

Final draft **ETSI EN 300 401** V1.4.1 (2006-01)

European Standard (Telecommunications series)

**Radio Broadcasting Systems;
Digital Audio Broadcasting (DAB) to mobile,
portable and fixed receivers**

European Broadcasting Union

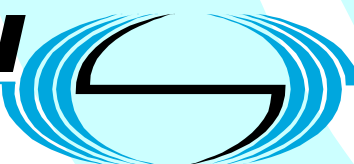


Union Européenne de Radio-Télévision

EBU-UER

DAB
Digital Audio Broadcasting

ETSI



Reference

REN/JTC-DAB-36

Keywords

audio, broadcasting, DAB, data, digital, satellite,
terrestrial

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Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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Foreword

This European Standard (Telecommunications series) has been produced by Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELEctrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI), and is now submitted for the ETSI standards One-step Approval Procedure.

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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The Eureka Project 147 was established in 1987, with funding from the European Commission, to develop a system for the broadcasting of audio and data to fixed, portable or mobile receivers. Their work resulted in the publication of European Standard, ETS 300 401 [7], for DAB (see note) which now has worldwide acceptance. The members of the Eureka Project 147 are drawn from broadcasting organizations and telecommunication providers together with companies from the professional and consumer electronics industry.

NOTE: DAB is a registered trademark owned by one of the Eureka Project 147 partners.

The present document on Digital Audio Broadcasting (DAB) is based on the overall system and service requirements adopted by the ITU-R Recommendation BS.774 [1] and ITU-R Recommendation BO.789 [2]. The DAB system has been recommended by the ITU-R, as Digital System A, for terrestrial and satellite delivery. The audio coding algorithm used by the DAB system has been subject to the standardization process within the ISO/Moving Pictures Expert Group (MPEG), see ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]. The layered ISO open system interconnect model ISO 7498-1 [4] has been used to the extent possible, and interfacing to information technology equipment and communications networks has been taken into account where applicable.

The present document defines the nature and content of the transmitted DAB signal with reference to the conceptual emission part. The emphasis is given to the normative elements. Informative elements are included only to the extent necessary to provide interpretative guidance to the DAB system users and equipment manufacturers.

The DAB system is a novel sound broadcasting system intended to supersede the existing analogue amplitude and frequency modulation systems. It is a rugged, yet highly spectrum and power efficient sound and data broadcasting system. It has been designed for terrestrial and satellite as well as for hybrid and mixed delivery. The DAB system has been publicly demonstrated on a number of occasions during its development. It has been subject to extensive field tests and computer simulations in Europe and elsewhere. It is now in regular service in many European countries and throughout the world. In 1995, the European DAB Forum (EuroDab) was established to pursue the introduction of DAB services in a concerted manner world-wide, and it became the World DAB Forum (World DAB) in 1997.

With respect to the previous version of EN 300 401 published in May 2001, the present document contains several refinements to the Eureka 147 DAB system. These refinements were performed and agreed by the World DAB Forum and include the following areas:

- backward compatible changes to PAD to provide greater flexibility;
- addition of Forward Error Correction mechanisms for packet mode service components;
- addition of extended labels and character definition;
- removal of some obsolete service information features;
- conditional access details moved to a separate ETSI document.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

1 Scope

The present document establishes a broadcasting standard for the Digital Audio Broadcasting (DAB) system designed for delivery of high-quality digital audio programme and data services for mobile, portable and fixed reception from terrestrial or satellite transmitters in the Very High Frequency (VHF)/Ultra High Frequency (UHF) frequency bands as well as for distribution through cable networks. The DAB system is designed to provide spectrum and power efficient techniques in terrestrial transmitter network planning, known as the Single Frequency Network (SFN) and the gap-filling technique. The DAB system is suitable for satellite as well as hybrid/mixed terrestrial/satellite broadcasting, using a simple, nearly omni-directional receiving antenna. The DAB system meets the required sharing criteria with other radiocommunication services.

The present document defines the DAB transmission signal. It includes the coding algorithms for audio, multiplexing of audio programme and data services, channel coding and modulation. A limited range of supplementary services associated with programme services is defined. Provision is also made for transmission of additional data services which may be programme related or not, within the limit of the total system capacity. The present document provides information on the system configuration which includes information about the ensembles, services, service components and linking of them. Provision is made for a compatible cross-reference to existing Frequency Modulation (FM) services and Amplitude Modulation (AM) services.

The present document describes the nominal characteristics of the emitted DAB signal. The aspects related to the receiver design are outside the scope of the present document. Hardware implementation considerations are not covered.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

- [1] ITU-R Recommendation BS.774 (1994): "Digital sound broadcasting to vehicular, portable and fixed receivers using terrestrial transmitters in the VHF/UHF bands".
- [2] ITU-R Recommendation BO.789 (1994): "Digital sound broadcasting to vehicular, portable and fixed receivers for BSS (sound) in the frequency range 500 - 3 000 MHz".
- [3] ISO/IEC 11172-3 (1993): "Information technology - Coding of moving pictures and associated audio for digital storage media at up to 1,5 Mbit/s - Part 3: Audio".
- [4] ISO 7498-1: "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".
- [5] CENELEC EN 62106: "Specification of the radio data system (RDS) for VHF/FM sound broadcasting in the frequency range from 87,5 to 108,0 MHz".
- [6] ITU-T Recommendation X.25: "Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit".
- [7] ETSI ETS 300 401 (1997): "Radio broadcasting systems; DAB to mobile, portable and fixed receivers".

- [8] ISO 3901 (2001): "Information and documentation - International Standard Recording Code (ISRC)".
- [9] IEC 60958 (all parts): "Digital audio interface".
- [10] ITU-R Recommendation BS.1284: "General methods for the subjective assessment of sound quality".
- [11] ISO/IEC 13818-3: "Information technology - Generic coding of moving pictures and associated audio information - Part 3: Audio".
- [12] DIN EN 797: "Bar coding - Symbology specifications: 'EAN/UPC'".
- [13] FINAL ACTS of the CEPT T-DAB Planning Meeting (3) (Maastricht, 2002): "For the revision of the Special Arrangement of the European Conference of Postal and Telecommunications Administrations (CEPT) relating to the use of the bands 47 - 68 MHz, 87.5 - 108 MHz, 174 - 230 MHz, 230 - 240 MHz and 1452 - 1492 MHz for the introduction of Terrestrial Digital Audio Broadcasting (T-DAB), Wiesbaden, 1995, as revised by the CEPT T-DAB planning meeting (2), Bonn, 1996".
- [14] ETSI EN 301 234: "Digital Audio Broadcasting (DAB); Multimedia Object Transfer (MOT) protocol".
- [15] ETSI TS 102 367: "Digital Audio Broadcasting (DAB); Conditional access".
- [16] ETSI TS 101 756: "Digital Audio Broadcasting (DAB); Registered Tables".
- [17] ETSI TS 102 368: "Digital Audio Broadcasting (DAB); DAB-TMC (Traffic Message Channel)".
- [18] ETSI ES 201 980: "Digital Radio Mondiale (DRM); System Specification".
- [19] ETSI TS 102 386: "Digital Radio Mondiale (DRM); AM signalling system (AMSS)".
- [20] ISO 10646: "Information technology - Universal Multiple-Octet Coded Character Set (UCS)".

3 Definitions, abbreviations, mathematical symbols, C-language mathematical symbols and conventions

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Access Control System (ACS): particular set of rules for managing entitlement checking and conditional access messages

alias component: mirrored signal component resulting from sub-Nyquist sampling

announcement cluster: group of services which share the same announcement interruption privileges

audio bit stream: sequence of consecutive audio frames

audio frame: frame of a duration of 24 ms (at 48 kHz sampling frequency) or of 48 ms (at 24 kHz sampling frequency) which contains a Layer II encoded audio signal ISO/IEC 11172-3 [3], ISO/IEC 13818-3 [11], corresponding to 1 152 consecutive audio samples

NOTE: It is the smallest part of the audio bit stream which is decodable on its own.

audio mode: audio coding system provides single channel, dual channel, stereo and joint stereo audio modes

NOTE: In each mode, the complete audio signal is encoded as one audio bit stream.

Auxiliary Information Channel (AIC): all or part of sub-channel 63, used to carry information redirected from the Fast Information Channel

bark: See "Critical band".

bit allocation: time-varying assignment of bits to samples in different sub-bands according to a psychoacoustic model

bound: lowest sub-band in which Intensity stereo coding is used, in the case of Joint stereo mode

Capacity Unit (CU): the smallest addressable unit (64 bits) of the Common Interleaved Frame (CIF)

Change Event Indication (CEI): set of FIG fields with particular values to indicate a change of database content for certain service information features

Common Interleaved Frame (CIF): serial digital output from the main service multiplexer which is contained in the Main Service Channel part of the transmission frame

NOTE: It is common to all transmission modes and contains 55 296 bits (i.e. 864 CUs).

Conditional Access (CA): mechanism by which the user access to service components can be restricted

convolutional coding: coding procedure which generates redundancy in the transmitted data stream in order to provide ruggedness against transmission distortions

critical band: psychoacoustic measure in the frequency domain which corresponds to the frequency selectivity of the human ear

NOTE: The unit of this psychoacoustic measure is called Bark. The Bark scale is a non-linear mapping of the frequency scale over the entire audio frequency range.

DAB audio frame: same as audio frame, but includes all specific DAB audio-related information

DAB transmission signal: transmitted radio frequency signal

database key: set of FIG fields that sub-divide a database for certain service information features

data service: service which comprises a non-audio primary service component and optionally additional secondary service components

dual channel mode: audio mode, in which two audio channels with independent programme contents (e.g. bilingual) are encoded within one audio bit stream

NOTE: The coding process is the same as for the Stereo mode.

energy dispersal: operation involving deterministic selective complementing of bits in the logical frame, intended to reduce the possibility that systematic patterns result in unwanted regularity in the transmitted signal

ensemble: transmitted signal, comprising a set of regularly and closely-spaced orthogonal carriers

NOTE: The ensemble is the entity which is received and processed. In general, it contains programme and data services.

Ensemble Identifier (EId): unique 16-bit code, allocated to an ensemble and intended to allow unambiguous world-wide identification of that ensemble

Equal Error Protection (EEP): error protection procedure which ensures a constant protection of the bit stream

Extended Programme Associated Data (X-PAD): extended part of the PAD carried towards the end of the DAB audio frame, immediately before the Scale Factor Cyclic Redundancy Check (CRC)

NOTE: Its length is variable.

Fast Information Block (FIB): data burst of 256 bits

NOTE: The sequence of FIBs is carried by the Fast Information Channel. The structure of the FIB is common to all transmission modes.

Fast Information Channel (FIC): part of the transmission frame, comprising the Fast Information Blocks, which contains the multiplex configuration information together with optional service Information and data service components

Fast Information Data Channel (FIDC): dedicated part of the Fast Information Channel which is available for non-audio related data services, such as paging

Fast Information Group (FIG): package of data used for one feature in the Fast Information Channel. Eight different types are available to provide a classification of the features

Fixed Programme Associated Data (F-PAD): fixed part of the PAD contained in the last two bytes of the DAB audio frame

intensity stereo coding: method of exploiting stereo irrelevance or redundancy in stereophonic audio programmes

NOTE: It is based on retaining only the energy envelope of the right and left channels at high frequencies. At low frequencies, the fine structure of the left and right channel of a stereophonic signal is retained.

joint stereo mode: audio mode in which two channels forming a stereo pair (left and right) are encoded within one bit stream and for which stereophonic irrelevance or redundancy is exploited for further bit reduction

NOTE: The method used in the DAB system is Intensity stereo coding.

logical frame: data burst, contributing to the contents of a sub-channel, during a time interval of 24 ms

EXAMPLE: Data bursts at the output of an audio encoder, a Conditional Access scrambler and a convolutional encoder are referred to as logical frames. The number of bits contained in a specific logical frame depends on the stage in the encoding process and the bit rate associated with the sub-channel.

logical frame count: value of the CIF counter corresponding to the first CIF which carries data from the logical frame

Main Service Channel (MSC): channel which occupies the major part of the transmission frame and which carries all the digital audio service components, together with possible supporting and additional data service components

masking: property of the human auditory system by which an audio signal cannot be perceived in the presence of another audio signal

masking threshold: function of frequency and time, specifying the sound pressure level below which an audio signal cannot be perceived by the human auditory system

MSC data group: package of data used for one user application in the Main Service Channel

NOTE: MSC data groups are transported in a series of one or more packets or X-PAD data sub-fields.

Multiplex Configuration Information (MCI): information defining the configuration of the multiplex

NOTE: It contains the current (and in the case of an imminent re-configuration, the forthcoming) details about the services, service components and sub-channels and the linking between these entities. It is carried in the FIC in order that a receiver may interpret this information in advance of the service components carried in the Main Service Channel. It also includes identification of the ensemble itself.

N: transform length of Fast Fourier Transform (FFT)

null symbol: first Orthogonal Frequency Division Multiplex (OFDM) symbol of the transmission frame

OFDM symbol: transmitted signal for that portion of time when the modulating phase state is held constant on each of the equi-spaced, equal amplitude carriers in the ensemble

NOTE: Each carrier is four-phase differentially modulated from one symbol to another, giving a gross bit rate of two bits per carrier per symbol.

packet mode: mode of data transmission in which data are carried in addressable blocks called packets

NOTE: Packets are used to convey MSC data groups within a sub-channel.

polyphase filter bank: set of equal-bandwidth filters with special phase relationship, allowing for efficient implementation of a filter bank

primary service component: first and mandatory component of a service

NOTE: It can be used as a default selection in the receiver.

programme: time-slice of a programme service, corresponding to an entry in a programme schedule

Programme Associated Data (PAD): information which is related to the audio data in terms of contents and synchronization

NOTE: The PAD field is located at the end of the DAB audio frame.

programme item: time-slice of a programme, for example, a piece of music or a news report

programme service: service which comprises an audio primary service component and optionally additional secondary service components

protection level: level specifying the degree of protection, provided by the convolutional coding, against transmission errors

protection profile: defines the scheme of convolutional coding applied

psychoacoustic model: mathematical model of the masking behaviour of the human auditory system

Scale Factor (ScF): factor by which a set of values is scaled before quantization

NOTE: The numerical code for the Scale Factor is called the Scale Factor Index.

Scale Factor Select Information (ScFSI): 2-bit code which indicates for each sub-band how many Scale Factors are coded within the audio frame

secondary service component: in case a service contains more than the primary service component, the additional service components are secondary service components

service: user-selectable output which can be either a programme service or a data service

service component: part of a service which carries either audio (including PAD) or data

NOTE: The service components of a given service are linked together by the Multiplex Configuration Information. Each service component is carried either in a sub-channel or in the Fast Information Data Channel.

Service Identifier (SId): 16-bit or 32-bit code used to identify a particular service

Service Information (SI): auxiliary information about services, such as service labels and programme type codes

service label: alphanumeric characters associated with a particular service and intended for display in a receiver

side information: information in the encoded audio bit stream which is necessary for controlling the audio decoder

NOTE: This information includes Bit Allocation, Scale Factor Select Information and Scale Factors.

single channel mode: audio mode, in which a monophonic audio programme is encoded within one bit stream

Single Frequency Network (SFN): network of DAB transmitters sharing the same radio frequency to achieve a large area coverage

stereo mode: audio mode, in which two channels forming a stereo pair (left and right) are encoded within one bit stream and for which the coding process is the same as for the Dual channel mode

stream mode: mode of data transmission within the Main Service Channel in which data are carried transparently from source to destination

NOTE: Data are carried in logical frames.

stuffing: one or more bits which may be inserted into the audio bit stream

NOTE: Stuffing bits are ignored by the audio decoding process. The purpose is to fill up a data field when required.

sub-band: subdivision of the audio frequency range

NOTE: In the audio coding system, 32 sub-bands of equal bandwidth are used.

sub-band samples: sub-band filter bank in the audio encoder creates a filtered and sub-sampled representation of the input audio signal

NOTE: The filtered samples are called sub-band samples. From 384 consecutive input audio samples, 12 consecutive sub-band samples are generated for each of the 32 sub-bands.

sub-channel: part of the Main Service Channel which is individually convolutionally encoded and comprises an integral number of Capacity Units per Common Interleaved Frame

synchronization channel: part of the transmission frame providing a phase reference

syncword: 12-bit code embedded in the MPEG Audio Layer II bit stream ISO/IEC 11172-3 [3], ISO/IEC 13818-3 [11] that identifies the beginning of an audio frame

transmission frame: actual transmitted frame, specific to the four transmission modes, conveying the Synchronization Channel, the Fast Information Channel and the Main Service Channel

transmission mode: specific set of transmission parameters (e.g. number of carriers, OFDM symbol duration)

NOTE: Four transmission modes (i.e. I, II, III and IV) are defined to allow the system to be used for different network configurations and a range of operating frequencies.

Unequal Error Protection (UEP): error protection procedure which allows the bit error characteristics to be matched with the bit error sensitivity of the different parts of the bit stream

User Application (UA): data application defined in a separate standard and fed with data via DAB (one FIDC, MSC packet or stream data service component transports data for one UA, whereas the PAD part of an MSC stream audio service component can transport data for up to 6 different UAs at a time)

X-PAD data group: package of data used for one user application in the Extended Programme Associated Data (X-PAD)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

A/D	Audio/Data
ACS	Access Control System
AES	Audio Engineering Society
AIC	Auxiliary Information Channel
AL	ALarm
AM	Amplitude Modulation
AppTy	Application Type
ASCTy	Audio Service Component Type
ASu	Announcement Support flags
ASw	Announcement Switching flags
BMP	Basic Multilingual Plane
C/N	Current/Next
CA	Conditional Access
CAId	Conditional Access Identifier
CAOrg	Conditional Access Organization
CEI	Change Event Indication
Chr	Character
CI	Contents Indicator
CIF	Common Interleaved Frame
CRC	Cyclic Redundancy Check
CU	Capacity Unit
d&t	date and time
DAB	Digital Audio Broadcasting
D-QPSK	Differential QPSK

DRC	Dynamic Range Control
DSCTy	Data Service Component Type
EAN	European Article Number
EBU	European Broadcasting Union
ECC	Extended Country Code
EEP	Equal Error Protection
EId	Ensemble Identifier
ETS	European Telecommunication Standard
EWS	Emergency Warning Systems
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FI	Frequency Information
FIB	Fast Information Block
FIC	Fast Information Channel
FIDC	Fast Information Data Channel
FIDCId	Fast Information Data Channel Identifier
FIG	Fast Information Group
FM	Frequency Modulation
F-PAD	Fixed Programme Associated Data
ID	Identifier of audio coding algorithm
IEC	International Electrotechnical Commission
ILS	International Linkage Set indicator
ISO	International Organization for Standardization
ISRC	International Standard Recording Code
LA	Linkage Actuator
LFN	Logical Frame Number
LSb	Least Significant bit
LSB	Least Significant Byte
LSF	Lower Sampling Frequency
LSI	Leap Second Indicator
LSN	Linkage Set Number
LTO	Local Time Offset
M/S	Music/Speech
MainId	Main Identifier of a transmitter
MCI	Multiplex Configuration Information
MJD	Modified Julian Date
MOT	Multimedia Object Transfer
MPEG	Moving Pictures Expert Group
MSb	Most Significant bit
MSB	Most Significant Byte
MSC	Main Service Channel
OE	Other Ensemble
OFDM	Orthogonal Frequency Division Multiplex
P/D	Programme/Data service flag
P/S	Primary/Secondary
PAD	Programme Associated Data
PCM	Pulse Coded Modulation
PI	Programme Identification code (RDS)
PIN	Programme Item Number (RDS)
PNum	Programme Number
PRBS	Pseudo-Random Binary Sequence
PTy	Programme Type
QPSK	Quadrature Phase Shift Keying
R&M	Range and Modulation
RDS	Radio Data System
Rfa	Reserved for future addition
Rfu	Reserved for future use
S/D	Static/Dynamic
SC	Service Component
ScF	Scale Factor
ScF-CRC	audio Scale Factor - Cyclic Redundancy Check (error check)
ScFSI	Scale Factor Select Information

SCId	Service Component Identifier
SCIdS	Service Component Identifier within the Service
SFN	Single Frequency Network
SI	Service Information
SId	Service Identifier
SIV	Service Information Version
SMR	Signal-to-Mask Ratio
SPL	Sound Pressure Level
SubChId	Sub-Channel Identifier
SubId	Sub-Identifier of a transmitter
TCId	Type Component Identifier
TD	Time Delay
TII	Transmitter Identification Information
TMC	Traffic Message Channel
TMIId	Transport Mechanism Identifier
UA	User Application
UEP	Unequal Error Protection
UHF	Ultra High Frequency
UPC	Universal Product Code
UTC	Co-ordinated Universal Time
VHF	Very High Frequency
X-PAD	eXtended Programme Associated Data

3.3 Mathematical symbols

For the purposes of the present document, the following mathematical symbols apply.

3.3.1 Arithmetic operators

\wedge	Power
$/$	Integer division with truncation of the result toward zero; for example, $7/4$ and $-7/-4$ are truncated to 1 and $-7/4$ and $7/-4$ are truncated to -1
$Q(a/b)$	$Q(a/b)$ is the quotient part of the division of a by b (a and b positive integers)
$R(a/b)$	$R(a/b)$ is the remainder of the division of a by b

$$\text{mod}(a,b) \text{ (b positive integer)} \quad \text{mod}(a,b) = \begin{cases} R(a/b) & \text{if } a \text{ is a positive integer} \\ R((b - R(-a/b))/b) & \text{if } a \text{ is a negative integer} \end{cases}$$

(mod p) Modulo p operation

3.3.2 Logical and set operators

$\max [,\dots,]$	The maximum value in the argument list
$\min [,\dots,]$	The minimum value in the argument list
\oplus	Exclusive or
\cap	Set intersection
\cup	Set union
\setminus	Set exclusion: $\{-3, -2, \dots, 3\} \setminus \{0\}$ is the set of integers $\{-3, -2, -1, 1, 2, 3\}$

3.3.3 Functions

sin	Sine
cos	Cosine
exp	Exponential
$e^{(\cdot)}$	Exponential function
$\sqrt{\quad}$	Square root
log10	Logarithm to base 10
j	Imaginary unit, $j^2 = -1$
Rect	$\text{Rect}(x) = \begin{cases} 1 & \text{if } 0 \leq x < 1 \\ 0 & \text{elsewhere} \end{cases}$
δ	Kronecker symbol $\delta(i,j) = \begin{cases} 1 & \text{if } i = j \\ 0 & \text{if } i \neq j \end{cases}$

3.3.4 Constants

π	3,14159265359...
e	2,71828182846...

3.4 C-language mathematical symbols

For the purposes of the present document, the following C-language mathematical symbols apply.

3.4.1 Arithmetic operators

+	Addition
-	Subtraction (as a binary operator) or negation (as a unary operator)
++	Increment
--	Decrement
*	Multiplication
DIV	Integer division with truncation of the result toward $-\infty$
%	Modulo operator. Defined only for positive numbers
log10	Logarithm to base 10

3.4.2 Logical operators

||	Logical OR
--	------------

3.4.3 Relational operators

>	Greater than
\geq	Greater than or equal to
<	Less than
\leq	Less than or equal to
==	Equal to
!=	Not equal to

3.4.4 Assignment

=	Assignment operator
---	---------------------

3.4.5 Mnemonics

The following mnemonics are defined to describe the different data types used in the coded DAB audio bit-stream:

bslbf	Bit string, left bit first, where "left" is the order in which bit strings are written in the present document. Bit strings are written as a string of 1 s and 0 s within single quote marks, e.g. "1000 0001". Blanks within a bit string are for ease of reading and have no significance
bound	Number of first sub-band in joint stereo mode
ch	Channel. If ch has the value 0 the left channel of a stereo signal or the first of two independent audio signals is indicated
chlimit	Number of channels
dscf	Difference between two Scale Factors
gr	Granule of three sub-band samples per sub-band
nbal	Number of allocated bits per sub-band sample
nch	Number of channels; equal to 1 for single channel mode, 2 in other modes
rpchof	Remainder polynomial coefficients, highest order first
sb	Sub-band
sblimit	The number of the lowest sub-band for which no bits are allocated
scfsi	Scale Factor selection information
uimsbf	Unsigned integer, most significant bit first

The byte order of multi-byte words is most significant byte first.

3.4.6 Method of describing bit stream syntax

The bit stream described in clause 7 is the bit stream that exists in the DAB-receiver at the interface between channel decoder and audio decoder. The bit stream is described using the "C" software language which is used to program the processor which assembles the programme audio and associated data for channel coding. Each data item in the bit stream is in bold type. It is described by its name, its length in bits, and a mnemonic for its type and order of transmission.

The action caused by a decoded data element in a bit stream depends on the value of that data element and on data elements previously decoded. The decoding of the data elements and definition of the state variables used in their decoding are described in annex B. The following constructs are used to express the conditions when data elements are present, and are in normal type.

NOTE 1: This syntax uses the "C"-code convention that a variable or expression evaluating to a non-zero value is equivalent to a condition that is true.

while (condition) {	If the condition is true, then the group of data elements occurs next in the data stream. This repeats until the condition is not true.
data_element	
...	
}	
do {	
data_element	The data element always occurs at least once.
...	
} while (condition)	The data element is repeated until the condition is not true.
if (condition) {	If the condition is true, then the first group of data elements occurs next in the data stream.
data_element	
...	
}	
else {	If the condition is not true, then the second group of data elements occurs next in the data stream.
data_element	
...	
}	
for (expr1; expr2; expr3) {	expr1 is an expression specifying the initialization of the loop.
data_element	Normally it specifies the initial state of the counter. expr2 is a condition specifying a test made before each iteration of the loop.
...	The loop terminates when the condition is not true.
}	expr3 is an expression that is performed at the end of each iteration of the loop, normally it increments a counter.

NOTE 2: The most common usage of this construct is as follows.

```
for ( i = 0; i < n; i++) {
    data_element
    ...
}
```

The group of data elements occurs n times. Conditional constructs within the group of data elements may depend on the value of the loop control variable i, which is set to zero for the first occurrence, incremented to one for the second occurrence, and so forth.

As noted, the group of data elements may contain nested conditional constructs. For compactness, the {} may be omitted when only one data element follows.

data_element [] data_element [] is an array of data. The number of data elements is indicated by the context.

data_element [n] data_element [n] is the (n+1)th element of an array of data.

data_element [m][n] data_element [m][n] is the (m+1),(n+1)th element of a two-dimensional array of data.

data_element [l][m][n] data_element [l][m][n] is the (l+1),(m+1),(n+1)th element of a three-dimensional array of data.

data_element [m..n] is the inclusive range of bits between bit m and bit n in the data_element.

3.5 Convention

Unless otherwise stated, the following notation, regarding the order of bits within each step of processing is used:

- in figures, the bit shown in the left hand position is considered to be first;
- in tables, the bit shown in the left hand position is considered to be first;
- in byte fields, the Most Significant bit (MSb) is considered to be first and denoted by the higher number. For example, the MSb of a single byte is denoted "b₇" and the Least Significant bit (LSb) is denoted "b₀";
- in vectors (mathematical expressions), the bit with the lowest index is considered to be first.

NOTE: Due to time-interleaving, this order of bits is not the true transmission order.

4 Basic DAB system description

The conceptual block diagram of the emission part of the DAB system is given in figure 1. Each block is labelled in order to indicate the function it performs.

The present document gives the description of the individual blocks in terms of their input/output transfer functions, as appropriate. The sequence of clauses in the present document generally follows the information flow in the left-to-right direction. The functions of the DAB system related to general transport mechanisms and multiplex control are given in clauses 5 and 6, respectively. Clause 7 describes a main function of the DAB system, i.e. audio coding. This is followed by the description of the available data features, in clause 8. Clauses 10 to 15 give the description of the transmission-related functions, as shown in the block diagram.

4.1 Transport mechanisms

General transport mechanisms used in the DAB system for transmission of digital audio programme and data services are described in clause 5.

Two mechanisms for transporting the data are defined: the FIC and the MSC.

The primary function of the FIC, which is made up of Fast Information Blocks (FIB), is to carry control information necessary to interpret the configuration of the MSC. The essential part of this control information is the Multiplex Configuration Information (MCI), which contains information on the multiplex structure and, when necessary, its re-configuration. Other types of information which can be included in the FIC represent the Service Information (SI), the Conditional Access (CA) management information and Fast Information Data Channel (FIDC). In order to allow a rapid and safe response to the MCI, the FIC is transmitted without time interleaving, but with a high level of protection against transmission errors.

The MSC is made up of a sequence of Common Interleaved Frames (CIF). A CIF is a data field of 55 296 bits, transmitted every 24 ms. The smallest addressable unit of the CIF is the Capacity Unit (CU), the size of which is 64 bits. Integral number of CUs are grouped together to constitute the basic transport unit of the MSC, called a sub-channel. The MSC constitutes therefore a multiplex of sub-channels.

For Service Components (SCs) in the MSC, two different transport modes are defined, the stream mode and the packet mode.

The stream mode provides a transparent transmission from source to destination at a fixed bit rate in a given sub-channel.

The packet mode is defined for the purpose of conveying several data service components into a single sub-channel. Each sub-channel may carry one or more service components.

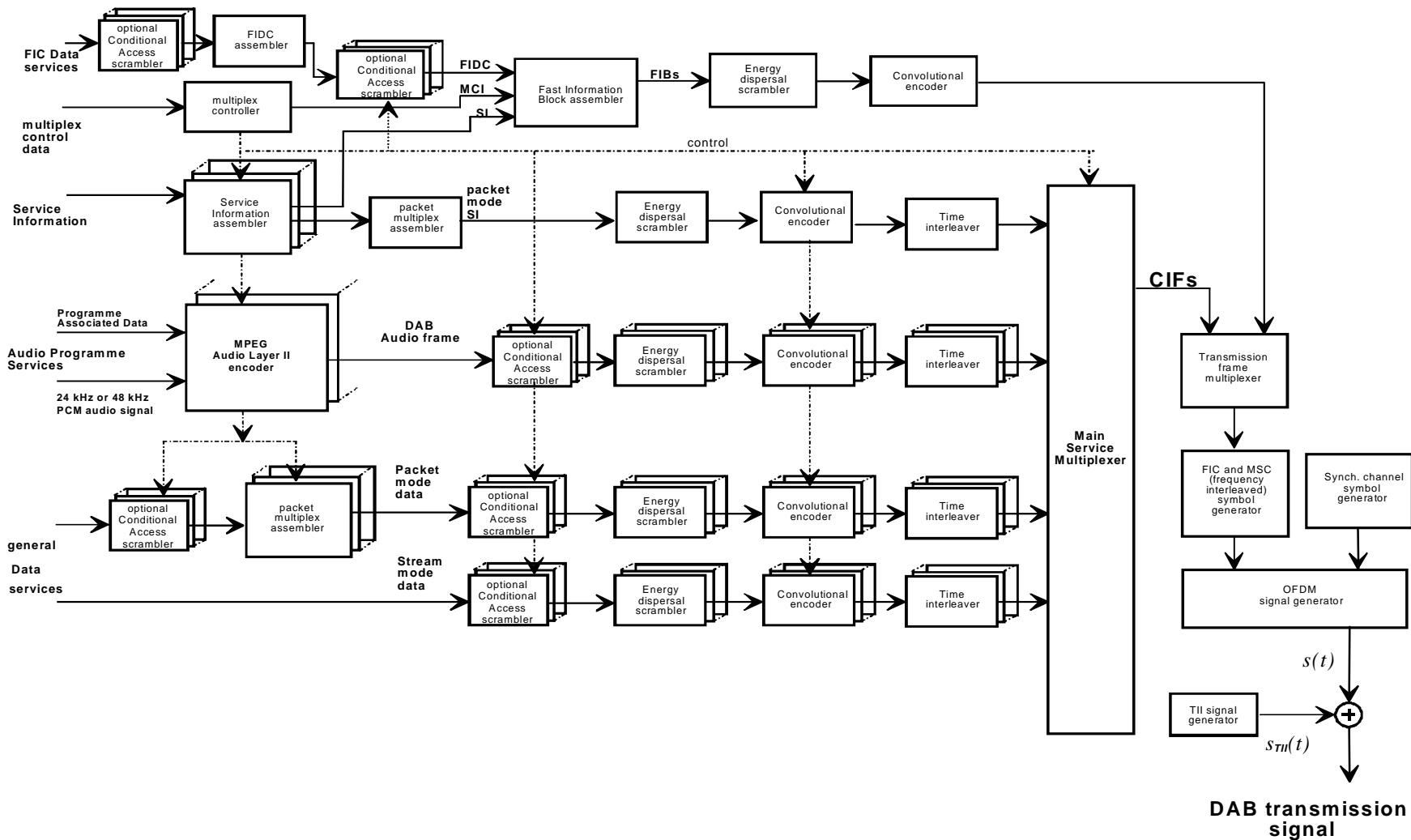


Figure 1: Conceptual DAB emission block diagram

4.2 Multiplex Configuration Information (MCI)

The Multiplex Configuration Information (MCI) of the system is described in clause 6.

The MCI is carried in the FIC. The MCI basically describes how the DAB multiplex is organized. Specifically, it provides the following information:

- a) defines the sub-channel organization;
- b) lists the services available in the ensemble;
- c) establishes links between services and service components;
- d) establishes links between sub-channels and service components;
- e) manages the multiplex re-configuration.

4.3 Audio coding

The coding algorithms applied to the audio signals as well as the structure of the encoded bit stream are described in clause 7. Additional information on the operations implemented at the encoder and at the decoder is given in the annexes A, B and C.

The DAB system uses MPEG Audio Layer II, suitably formatted for DAB transmission. For 48 kHz sampling frequency it uses the ISO/IEC 11172-3 [3] and for 24 kHz sampling frequency it uses the ISO/IEC 13818-3 [11].

The encoder processes the input Pulse Coded Modulation (PCM) audio signal, sampled at 48 kHz or 24 kHz, and produces the compressed audio bit stream of different bit rates ranging from 8 kbit/s to 384 kbit/s.

Four audio modes are provided:

- a) single channel (i.e. mono) mode;
- b) dual channel (i.e. two mono channels) mode;
- c) stereo mode;
- d) joint stereo mode.

The need for an additional coding mode, for multi-channel sound, has been anticipated. The multi-channel sound will comprise a conventional stereo signal, decodable by a stereo decoder, plus the additional information for the reproduction of the multi-channel sound. Multi-channel sound services will be identified by a particular Audio Service Component Type (ASCTy) code, as specified in clause 6.3.1.

The Layer II of ISO/IEC 11172-3 [3] contains the basic filtering of the digital audio input into 32 sub-bands, fixed segmentation to format the data into blocks, a psychoacoustic model to determine the Bit Allocation (BAI), and quantization using block companding and frame coding. It also provides coding of the BAI, ScFs and audio sample data. The psychoacoustic model is not rigidly determined and may use various estimations of the auditory masking thresholds; nevertheless, the DAB audio frame shall conform to the provisions of clause 7.

Each audio frame contains a number of bytes which may be used to carry the Programme Associated Data (PAD), i.e. the information that is related to the audio in terms of contents and synchronization. The PAD contains two bytes of Fixed PAD (F-PAD), and an optional extension called the Extended PAD (X-PAD). Functions available for the F-PAD part include Dynamic Range Control (DRC), music/speech indication, etc. User Applications and the dynamic label can travel in the X-PAD part.

4.4 Data features

The provision of data features which can be carried either in the MSC or in the FIC, is described in clause 8.

The Service Information (SI) features which may be carried in the FIC include the following: Service component language, Service linking, Date and time (d&t), Programme Number (PNum), Programme Type (PTy), announcements, Regional identification, Other Ensembles, FM and AM services information, Frequency Information (FI), Transmitter Identification Information (TII), ensemble, service and service component labels, etc. It is also possible to redirect certain features to the MSC.

The Fast Information Data Channel (FIDC) carried in the FIC includes provision for paging, Traffic Message Channel (TMC), Emergency Warning System (EWS), etc. It is generally considered that, due to the limited capacity of the FIC, priority should be given to the system-control related information, i.e. the MCI.

4.5 Conditional Access (CA)

General provisions for Conditional Access (CA) are given in TS 102 367 [15].

The purpose of CA is to permit the service and/or service components to be made incomprehensible to unauthorized users.

The MCI includes the appropriate parameters to indicate whether service components are scrambled or not, and how to find the parameters necessary for descrambling.

4.6 Energy dispersal

Clause 10 describes the energy dispersal of the DAB signal. The purpose is to avoid the transmission of signal patterns which might result in an unwanted regularity in the transmitted signal.

4.7 Convolutional coding

The process of convolutional coding is applied at the output of each energy dispersal scrambler. The convolutional coding process described in clause 11 consists of generating redundancy as part of the error protection mechanism required to combat adverse propagation conditions.

The convolutional coding parameters depend on the type of service carried, the net bit rate, and the desired level of error protection. Two error protection procedures are available: Unequal Error Protection (UEP) and Equal Error Protection (EEP). The former is primarily designed for audio but can be used for data. The latter can be used for audio as well as for data.

4.8 Time interleaving

The process of time interleaving described in clause 12 is applied at the output of each convolutional encoder contributing to the sub-channels in the MSC. It is not applied to the FIC.

4.9 Common Interleaved Frame (CIF)

Clause 13 describes how the convolutionally-encoded and time-interleaved logical frames constituting the sub-channels, are combined into a structure called the Common Interleaved Frame (CIF). A CIF consists of 55 296 bits, grouped into 864 Capacity Units (CU) and is transmitted every 24 ms. The configuration of the CIF is signalled by the Multiplex Configuration Information (MCI) carried in the FIC.

4.10 DAB transmission signal

The description of the DAB transmission signal in the temporal domain is given in clause 14. In order to allow the DAB system to be used in different transmission network configurations and over a wide range of operating frequencies, four transmission modes are defined. The transmitted signal has a frame structure of 96 ms duration (Transmission mode I), 24 ms (Transmission modes II and III) and 48 ms (Transmission mode IV). It consists of consecutive Orthogonal Frequency Division Multiplex (OFDM) symbols. The OFDM symbols are generated from the output of the multiplexer which combines the CIFs and the convolutionally encoded FIBs. Their generation involves the processes of Differential Quadrature Phase Shift Keying (D-QPSK), frequency interleaving, and D-QPSK symbols frequency multiplexing (OFDM generator).

The transmission frame consists of a sequence of three groups of OFDM symbols: synchronization channel symbols, Fast Information Channel symbols and Main Service Channel symbols. The synchronization channel symbols comprise the null symbol and the phase reference symbol.

The null symbols are also used to allow a limited number of OFDM carriers to convey the Transmitter Identification Information (TII).

4.11 Radio frequency parameters

Clause 15 specifies the permitted values of the central frequency of the DAB ensemble and indicates the frequency limits under which the four DAB transmission modes are designed to operate. Elements on time and spectrum characteristics of the emitted signal are also given.

4.12 Main DAB system characteristics

The main DAB system characteristics are summarized in table 1.

Table 1: Main DAB system characteristics

	Main DAB system elements	Features		Clause
1	DAB system inputs	audio programme services data services Programme Associated Data Multiplex Configuration Information Service Information	audio input format: PCM audio samples sampling rate: 48 kHz or 24 kHz input resolution: up to 22 bits/sample	clause A.1
2	Audio coding standard MPEG Audio Layer II	audio modes audio bit rates for ISO/IEC 11172-3 [3] sampling rate 48 kHz audio frame duration for ISO/IEC 11172-3 [3] audio bit rates for ISO/IEC 13818-3 [11] sampling rate 24 kHz (LSF coding) audio frame duration for ISO/IEC 13818-3 [11]	single channel stereo dual channel joint stereo 32, 48, 56, 64, 80, 96, 112, 128, 160, 192 kbit/s for single channel 64, 96, 112, 128, 160, 192, 224, 256, 320, 384 kbit/s for stereo, joint stereo and dual channel 24 ms 8, 16, 24, 32, 40, 48, 56, 64, 80, 96, 112, 128, 144, 160 kbit/s for all audio modes 48 ms	clauses 7.2.1.3 and A.2

	Main DAB system elements	Features		Clause
3	Main user information contained in audio header	audio mode copyright original/copy		clause 7.2.1.3
4	Programme Associated Data (PAD)	fixed PAD available data capacity: 667 bit/s for 24 ms frame and 333 bit/s for 48 ms frame extended PAD	dynamic range control music/speech indication command channel ISRC and UPC/EAN dynamic label user applications	clauses 7.4, A.3 and A.4
5	Protection mechanisms for audio	Audio side information CRC Scale Factor CRC		clauses 7.3.1.4, 7.3.2.8 and annex E
6	Fast Information Block (FIB)	Data field of size 256 bits carried in the FIC; independent on the transmission mode	Different types of data can be contained in a FIB (see rows 9, 10, 12 and 14)	clause 5.2.1
7	Transport modes in the MSC	stream mode packet mode	one service component per sub-channel can be transmitted transparently at a fixed bit rate The packet structure supports multiplexing of various service components in one sub-channel; a sequence of packets is conveyed in a sub-channel	clauses 5.3.1, 5.3.2 and 5.3.3
8	General data transport channels	Main Service Channel (MSC) - time and frequency interleaved Fast Information Channel (FIC) - frequency interleaved	MSC carries audio and data service components FIC carries the Multiplex Configuration Information (MCI), SI and optionally data service components; allows for rapid access of information by the receiver	clause 5
9	Multiplex Configuration Information (MCI)	The MCI provides repetitive information about ensembles, services, service components, sub-channels and linking of them	The MCI of a future multiplex configuration is sent in advance to allow for continuity of services	clause 6 and annex D
10	Service Information (SI)	Service component language Time and country identifier Programme Number Programme Type Announcements DRM services Frequency Information Transmitter identification Other ensembles FM services FIC re-direction Ensemble label Service label Service linking information Regional identification AMSS services AM services User application information		clause 8.1
11	Auxiliary Information Channel (AIC)	A part of sub-channel 63 in the MSC is used to carry data which cannot be accommodated in the FIC	Packet address 1023	clauses 5.4 and 8.1.12
12	Fast Information Data Channel (FIDC)	Data for UAs carried in the FIC	Paging Traffic Message Channel Emergency Warning Systems	clause 8.2
13	Conditional Access (CA)	The CA may be applied to audio and data service components	scrambling/descrambling entitlement checking entitlement management	see TS 102 367 [15]
14	Energy dispersal	Energy dispersal is applied to avoid unwanted regularity in the transmitted signal		clause 10

	Main DAB system elements	Features		Clause
15	Channel protection mechanisms	Convolutional coding is applied	UEP: 5 protection levels with Unequal Error Protection EEP: two sets of 4 protection levels with Equal Error Protection	clause 11
16	Time interleaving	interleaving depth: 16 logical frames (384 ms)		clause 12
17	Common Interleaved Frame (CIF)	Data field of size 55 296 bits, carrying the MSC information; independent of transmission mode		clause 13
18	Frequency interleaving	distributes the convolutionally encoded data over the bandwidth of 1,5 MHz		clause 14.6
19	DAB transmission frame	comprises the following OFDM symbols: - Null symbol - Phase Reference symbol - FIC symbols - MSC symbols		clause 14.1
20	Transmission modes	Transmission mode I: intended for SFN in Bands I, II and III Transmission mode II: intended for local services in Bands I, II, III, IV, V and L-band Transmission mode III: intended for frequencies below 3 GHz and cable Transmission mode IV: intended for local services in Bands I, II, III, IV, V and L-band (for optimum SFN operation in L-band)	number of carriers: 1 536 carrier spacing: 1 kHz symbol duration: 1,246 μ s guard interval: 246 μ s number of carriers: 384 carrier spacing: 4 kHz symbol duration: 312 μ s guard interval: 62 μ s number of carriers: 192 carrier spacing: 8 kHz symbol duration: 156 μ s guard interval: 31 μ s number of carriers: 768 carrier spacing: 2 kHz symbol duration: 623 μ s guard interval: 123 μ s	clause 14.2
21	Modulation	differentially encoded Quadrature Phase Shift Keying (D-QPSK)		clause 14.7
22	RF characteristics	Time and spectrum characteristics		clause 15

5 Transport mechanisms

5.1 Introduction

The DAB system is designed to carry several digital audio signals together with data signals. Audio and data signals are considered to be service components which can be grouped together to form services (see clause 6). This clause describes the main transport mechanisms available in the DAB multiplex.

The DAB transmission system combines three channels (see also clause 14.1):

- 1) **Main Service Channel (MSC):** used to carry audio and data service components. The MSC is a time-interleaved (see clause 12) data channel divided into a number of sub-channels which are individually convolutionally coded, with equal or unequal error protection (see clause 11.3). Each sub-channel may carry one or more service components. The organization of the sub-channels and service components is called the multiplex configuration.

- 2) **Fast Information Channel (FIC):** used for rapid access of information by a receiver. In particular it is used to send the Multiplex Configuration Information (MCI) (see clause 6) and optionally Service Information and data services (see clause 8). The FIC is a non-time-interleaved data channel with fixed equal error protection (see clause 11.2).
- 3) **Synchronization channel:** used internally within the transmission system for basic demodulator functions, such as transmission frame synchronization, automatic frequency control, channel state estimation, and transmitter identification. The synchronization channel is described in clause 14.3 and no further details are given here.

Each channel supplies data from different sources and these data are provided to form a transmission frame (see also figure 1). A more detailed description is given in clause 14.2.

Both the organization and length of a transmission frame depend on the transmission mode (see clauses 14 and 15.1). The Fast Information Block (FIB) and the Common Interleaved Frame (CIF) are introduced in order to provide transmission mode independent data transport packages associated with the FIC and MSC respectively (see figure 2).

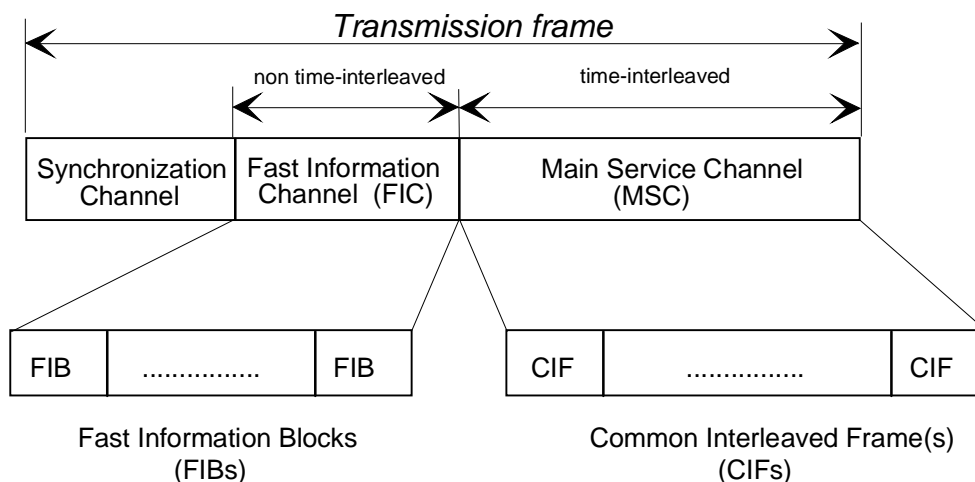


Figure 2: Transmission mode independent description of the FIC and MSC

Table 2 gives the transmission frame duration and the number of FIBs and CIFs which are associated with each transmission frame for the four transmission modes.

Table 2: General transport characteristics of the transmission frame

Transmission mode	Duration of transmission frame	Number of FIBs per transmission frame	Number of CIFs per transmission frame
I	96 ms	12	4
II	24 ms	3	1
III	24 ms	4	1
IV	48 ms	6	2

In transmission mode I, the 12 FIBs contributing to one transmission frame shall be divided into four groups which are each assigned to one of the CIFs contributing to the same transmission frame. The information contained in the first three FIBs shall refer to the first CIF, the information contained in the fourth, fifth and sixth FIB to the second CIF, and so on. All FIBs contributing to a transmission frame, in transmission modes II and III, shall be assigned to the one CIF associated with that transmission frame. In transmission mode IV, the six FIBs contributing to one transmission frame shall be divided into two groups which are each assigned to one of the CIFs contributing to the same transmission frame. The information contained in the first three FIBs shall refer to the first CIF, and the information contained in the fourth, fifth and sixth FIB to the second CIF.

The following clauses describe the formation of the FIC and MSC.

5.2 Fast Information Channel (FIC)

The FIC is made up of FIBs.

5.2.1 Fast Information Block (FIB)

The general structure of the FIB is shown in figure 3, for a case when the useful data does not occupy the whole of a FIB data field. The FIB contains 256 bits and comprises an FIB data field and a CRC.

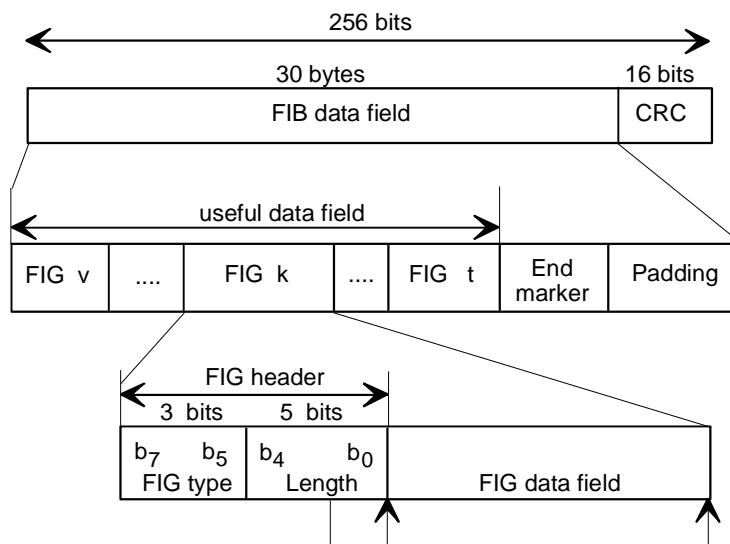


Figure 3: Structure of the FIB

FIB data field: the FIB data field shall be organized in bytes allocated to useful data, an end marker and padding in the following way:

- the useful data occupy the whole 30 bytes of the FIB data field. In this case, there shall be no end marker and no padding bytes;
- the useful data occupy 29 bytes of the FIB data field. In this case, there shall be an end marker but no padding bytes;
- the useful data occupy less than 29 bytes. In this case, there shall be both an end marker and padding bytes;
- there is no useful data. In this case, the FIB data field shall begin with an end marker and the rest of the FIB data field contains padding bytes.

The FIB data field is described as follows:

- **Useful data field:** this contains one or more Fast Information Groups (FIGs) (see clause 5.2.2).
- **End marker:** is a special FIG and shall have a FIG header field (111 11111) and no FIG data field.
- **Padding:** this field shall contain the bytes required to complete the FIB data field. The padding byte field shall contain all zeroes.
- **CRC:** a 16-bit Cyclic Redundancy Check word is calculated on the FIB data field and shall be generated according to the procedure defined in annex E. The generation shall be based on the polynomial $G(x) = x^{16} + x^{12} + x^5 + 1$ (ITU-T Recommendation X.25 [6]).

At the beginning of each CRC word calculation, all shift register stage contents shall be initialized to "1". The CRC word shall be complemented (1's complement) prior to transmission.

5.2.2 Fast Information Group (FIG)

The FIG shall comprise the FIG header and the FIG data field (see figure 3). The following definitions apply:

FIG header: shall contain the FIG type and the length:

- **FIG type:** this 3-bit field shall indicate the type of data contained in the FIG data field. The assignment of FIG types is given in table 3.

Table 3: List of FIG types

FIG type number	FIG type	FIG application
0	000	MCI and part of the SI
1	001	Labels, etc. (part of the SI)
2	010	Labels, etc. (part of the SI)
3	011	Reserved
4	100	Reserved
5	101	FIC Data Channel (FIDC)
6	110	Conditional Access (CA)
7	111	Reserved (except for Length 31)

- **Length:** this 5-bit field shall represent the length in bytes of the FIG data field and is expressed as an unsigned binary number (MSb first) in the range 1 to 29. Values 0, 30 and 31 shall be reserved for future use of the FIG data field except for 31 ("11111") when used with FIG type 7 ("111") which is used for the end marker.

FIG data field: this field is described in clauses 5.2.2.1 to 5.2.2.4, 6.2 to 6.4 and clause 8.

Generally, FIGs may be arranged in any order except where special operational requirements dictate otherwise. FIGs shall not be split between FIBs. FIG types 0, 1, 2, 5 and 6 are defined in clauses 5.2.2.1 to 5.2.2.4.

5.2.2.1 MCI and SI: FIG type 0 data field

The FIG type 0 is used to signal the current and future multiplex configuration, a multiplex re-configuration, time and date and other basic Service Information. The structure of the FIG type 0 data field is shown in figure 4.

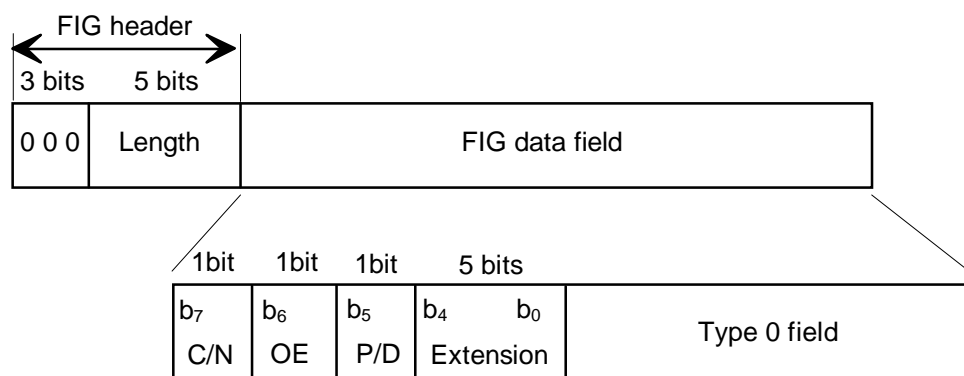


Figure 4: Structure of the FIG type 0 data field

The following definitions apply:

Current/Next (C/N): this 1-bit flag shall indicate one of two situations, as follows:

- the type 0 field applies to the current or the next version of the multiplex configuration, as follows:
 - 0: current configuration;
 - 1: next configuration.

The C/N flag applies to situation (a) for the Extensions associated with multiplex configuration features: these are Extensions 1 to 4, 8 and 14 (see also clause 6).

- b) the type 0 field carries information for a database. The database may be large and require more than one FIG to transport. The C/N flag indicates the Service Information Version (SIV). Certain Extensions divide the database into smaller portions each addressed by use of a database key. When the database is defined, the C/N flag is used to indicate the first FIG carrying data for the database or subsequent FIGs. Any change to the contents of the database is signalled by sending a Change Event Indication (CEI) which is a FIG with certain parameters set to particular values.

When the database is being defined, the C/N flag is used as follows:

- 0: start of database;
- 1: continuation of database.

When a change to the database needs to be signalled, using the CEI, the C/N flag is used as follows:

- 0: change event;
- 1: reserved for future use.

The C/N flag applies to situation (b) for Extensions 6, 9, 11, 18, 21, 22, 24, 25, and 27 (see clauses 8.1.15, 8.1.3.2, 8.1.16.1, 8.1.6.1, 8.1.8, 8.1.9, 8.1.10.2, 8.1.10.5.1 and 8.1.11.2.1, respectively). The database key and CEI are defined individually for each Extension.

For those Extensions which do not use this flag, the bit b_7 shall be reserved for future use of the type 0 field. This Reserved for future use (Rfu) bit shall be set to "0" for the currently specified extension field and type 0 field.

Other Ensemble (OE): this 1-bit flag shall indicate whether the information is related to this or another ensemble, as follows:

- 0: this ensemble;
- 1: other ensemble (or FM or AM or DRM service).

The OE flag is used to indicate "other ensembles" for Extensions 6, 13, 16, 17, 21, and 24 (see clauses 8.1.15, 8.1.20, 8.1.4, 8.1.5.1, 8.1.8 and 8.1.10.2, respectively). For Extensions 16 and 17 it may also indicate FM, AM or DRM services (see clauses 8.1.11.3, 8.1.11.4, 8.1.19.2 and 8.1.19.3). For Extension 21 the OE flag may also indicate FM and AM services (see clauses 8.1.11.1, 8.1.8 and 8.1.19.1).

For those Extensions which do not use this flag, the bit b_6 shall be reserved for future use of the type 0 field. This Rfu bit shall be set to "0" for the currently specified Extension field and type 0 field.

P/D: this 1-bit flag shall indicate whether the Service Identifiers (SIDs) are in the 16-bit or 32-bit format, as follows:

- 0: 16-bit SID, used for programme services;
- 1: 32-bit SID, used for data services.

The P/D flag is used for Extensions 2, 6, 8, 9, 13 and 24 (see clauses 6.3.1, 8.1.15, 6.3.6, 8.1.3.2, 8.1.20 and 8.1.10.2, respectively). When the P/D flag is not used, the Service Identifier (SID) takes the 16-bit format.

For those Extensions which do not use this flag, the bit b_5 shall be reserved for future use of the type 0 field. This Rfu bit shall be set to "0" for the currently specified extension field and type 0 field.

NOTE: 16-bit and 32-bit Service Identifiers may not be mixed in the same type 0 field.

Extension: this 5-bit field, expressed as an unsigned binary number, identifies one of 32 interpretations of the FIG type 0 field (see clauses 6.2, 6.3, 6.4 and 8.1). Those extensions, which are not defined, are reserved for future use.

5.2.2.2 Labels: FIG type 1 and FIG type 2 data fields

5.2.2.2.1 FIG type 1

The FIG type 1 is used to signal labels for display. The structure of the FIG type 1 data field is shown in figure 5.

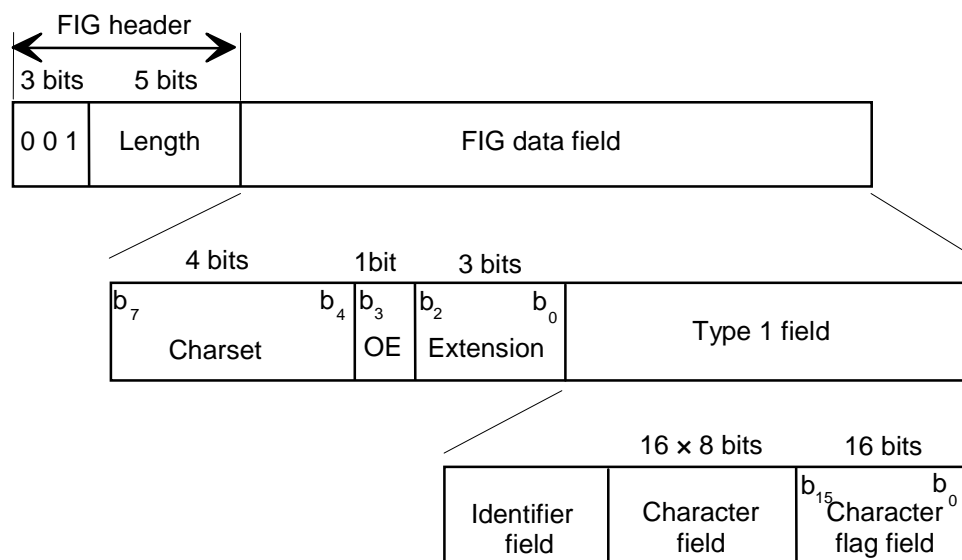


Figure 5: Structure of the FIG type 1 data field

The following definitions apply:

Charset: this 4-bit field shall identify a character set to qualify the character information contained in the FIG type 1 field. The interpretation of this field shall be as defined in TS 101 756 [16], table 1.

OE: this 1-bit flag shall indicate whether the information is related to this or another ensemble, as follows:

0: this ensemble;

1: other ensemble (or FM or AM services).

The OE flag is used to indicate "other ensembles" for Extensions 0, 1, 4 and 5 (see clauses 8.1.13 and 8.1.14). For Extension 1 it may also indicate an FM or an AM service (see clause 8.1.14.1).

For those extensions which do not use this flag, the bit b_3 shall be reserved for future use. The Rfu bit is set to "0" for the currently specified extension field and FIG type 1 field.

Extension: this 3-bit field, expressed as an unsigned binary number, shall identify one of 8 interpretations of the FIG type 1 field (see clause 8.1). Those extensions, which are not defined, are reserved for future use.

Identifier field: this field is defined individually for each extension of the FIG type 1 field (see clause 8.1).

Character field: this 16-byte field shall define the label. It shall be coded as a string of up to 16 characters, which are chosen from the character set signalled by the Charset field in the first byte of the FIG type 1 data field. The characters are coded from byte 15 to byte 0. The first character starts at byte 15.

Character flag field: this 16-bit flag field shall indicate which of the characters of the character field are to be displayed in an abbreviated form of the label, as follows:

b_i : ($i = 0, \dots, 15$);

0: not to be displayed in abbreviated label;

1: to be displayed in abbreviated label.

NOTE: Not more than 8 of the b_i may be set to "1".

If the character field contains less than 16 characters, the unused bits in the character flag field (having no corresponding character) shall be set to zero.

5.2.2.2.2 FIG type 2

The FIG type 2 is used to signal labels that require more than 16 bytes to carry the label. The structure of the FIG type 2 data field is shown in figure 6.

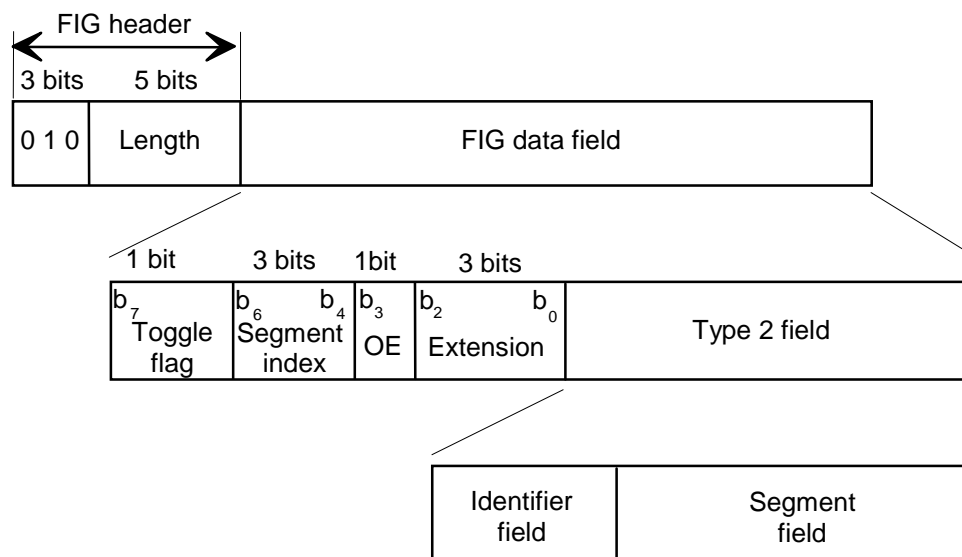


Figure 6: Structure of the FIG type 2 data field

The following definitions apply:

Toggle flag: this bit shall be maintained in the same state for all segments of the same label. When a label is changed, this bit shall be inverted with respect to its previous state. When a label, which may consist of several segments, is repeated, then this bit shall remain unchanged.

Segment index: this 3-bit field, expressed as an unsigned binary number in the range 0 to 7, shall define the index of the segment field carried in the FIG type 2 field (see clause 5.5).

OE: this 1-bit flag shall indicate whether the information is related to this or another ensemble, as follows:

0: this ensemble;

1: other ensemble (or FM or AM services).

The OE flag is used to indicate "other ensembles" for Extensions 0, 1, 4 and 5 (see clauses 8.1.13 and 8.1.14). For Extension 1 it may also indicate an FM or an AM service (see clause 8.1.14.1).

For those extensions which do not use this flag, the bit b₃ shall be reserved for future use. The Rfu bit is set to "0" for the currently specified extension field and FIG type 2 field.

Extension: this 3-bit field, expressed as an unsigned binary number, shall identify one of 8 interpretations of the FIG type 2 field (see clauses 5.5 and 8.1). Those extensions, which are not defined, are reserved for future use.

Identifier field: this field is defined individually for each extension of the FIG type 2 field (see clauses 5.5 and 8.1).

Segment field: this variable length field carries one segment of the extended label data field (see clause 5.5).

5.2.2.3 FIDC: FIG type 5 data field

The FIG type 5 is used for the Fast Information Data Channel (FIDC). The structure of the FIG type 5 data field is shown in figure 7.

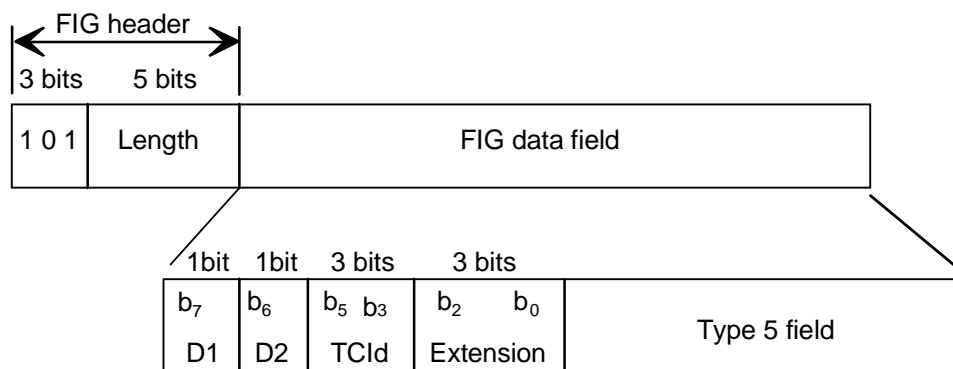


Figure 7: Structure of the FIG type 5 data field

The following definitions apply:

D1, D2: these 1-bit flags are defined for each extension individually (see clause 8.2).

TCId (Type Component Identifier): this 3-bit field shall identify one of eight different service components which may be carried using the same extension number.

Extension: this 3-bit field, expressed as an unsigned binary number, shall identify one of 8 interpretations of the FIG type 5 field (see clause 8.2). Those extensions, which are not defined, are reserved for future use.

5.2.2.4 CA: FIG type 6 data field

The FIG type 6 is used to send Conditional Access related parameters. The structure of the FIG type 6 data field is defined in TS 102 367 [15].

5.3 Main Service Channel (MSC)

The MSC is made up of Common Interleaved Frames (CIFs). The CIF contains 55 296 bits. The smallest addressable unit of the CIF is the Capacity Unit (CU), comprising 64 bits. Therefore, the CIF contains 864 CUs, which shall be identified by the CU addresses 0 to 863. The bit structure of the CIF is described in clause 13.

The MSC is divided into sub-channels. Each sub-channel shall occupy an integral number of consecutive CUs and is individually convolutionally encoded. Each CU may only be used for one sub-channel. A service component is a part of a service which carries either audio or general data. The DAB service structure is explained in clause 6.1.

The data, carried in the MSC, shall be divided at source into regular 24 ms bursts corresponding to the sub-channel data capacity of each CIF. Each burst of data constitutes a logical frame. Each logical frame is associated with a corresponding CIF. Succeeding CIFs are identified by the value of the CIF counter, which is signalled in the MCI (see clause 6.4).

The logical frame count is a notional count which shall be defined as the value of the CIF counter corresponding to the first CIF which carries data from the logical frame.

There are two transport modes in the MSC: one is called the stream mode and the other the packet mode.

5.3.1 Stream mode

The stream mode allows a service application to accept and deliver data transparently from source to destination. At any one time, the data rate of the application shall be fixed in multiples of 8 kbit/s. The application shall either supply information on demand, or include a method of handling data asynchronously at a lower rate. Data shall be divided into logical frames.

5.3.2 Packet mode - network level

The packet mode allows different data service components to be carried within the same sub-channel. The permissible data rates for the sub-channel shall be multiples of 8 kbit/s. Data may be carried in data groups (see clause 5.3.3) or transported using packets alone. The value of the DG flag (see clause 6.3.2) indicates which mode is used. The sub-channel may have additional Forward Error Correction applied to further mitigate against transmission errors (see clause 5.3.5).

A packet shall be identified by an address. Packets with different addresses may be sent in any order in a sub-channel. However, the sequence of packets with the same address shall be maintained.

Packets shall have a fixed length and four standard packet length types are allowed (see table 4). It is permissible to mix packet types of several lengths in a sub-channel provided that there is an integral number of packets per logical frame. Padding packets shall be used, if necessary to adjust the data rate to the required multiple of 8 kbit/s.

The links between the service component and the packet address are given in the MCI (see clause 6.3.2).

A packet shall consist of a Packet header, a Packet data field and a Packet CRC (see figure 8).

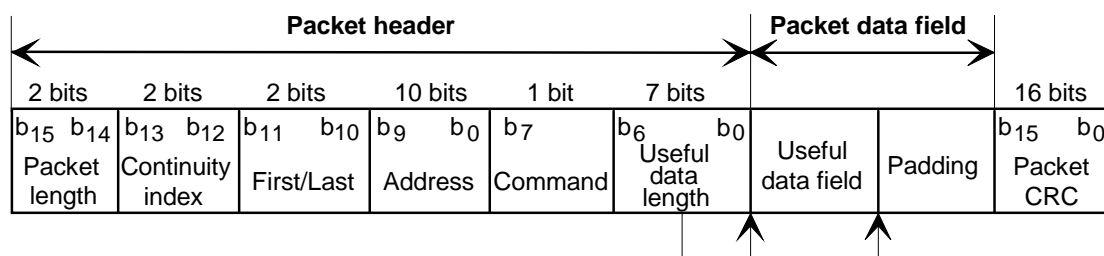


Figure 8: Packet structure

5.3.2.1 Packet header

The packet header has a length of 3 bytes and it shall comprise the following parameters:

- **Packet length:** four different packet data field lengths are allowed, see table 4.

Table 4: Packet length

Packet length b ₁₅ b ₁₄	Packet length (in bytes)	Packet data field length (in bytes)
0 0	24	19
0 1	48	43
1 0	72	67
1 1	96	91

- **Continuity index:** this 2-bit, modulo-4 counter shall be incremented by one for each successive packet in a series having the same address. It provides the link between successive packets, carrying the same service component, regardless of length.

- **First/Last:** these two flags shall be used to identify particular packets which form a succession of packets, carrying data groups of the same service component (see clause 5.3.3). For service components that are transported without data groups, the flags shall be set to 0. When data groups are used, the flags shall be assigned as in table 5.

Table 5: First/Last flags for packet mode

First	b ₁₁	Last	b ₁₀	The packet is the:
0		0		intermediate packet of a series
0		1		last packet of a series
1		0		first packet of a series
1		1		the one and only packet

- **Address:** this 10-bit field shall identify packets carrying a particular service component within a sub-channel. Address 0 shall be used for padding packets and shall not be assigned to any service component. Up to 1 023 service components may be carried simultaneously in a sub-channel.
- **Command:** this 1-bit flag shall indicate whether the packet is used for general data or for special commands.

EXAMPLE: In conjunction with conditional access, see TS 102 367 [15]) as follows:

0: data packet;

1: command packet.

- **Useful data length:** this 7-bit field, coded as an unsigned binary number (in the inclusive range 0 to 91), shall represent the length in bytes of the associated useful data field.

5.3.2.2 Packet data field

This field contains the useful data field and padding.

Useful data field: this field shall contain the useful service component data.

Padding: this field shall comprise the bytes required to complete the packet data field according to the number of bytes given in table 4. The padding byte field shall contain all zeroes.

5.3.2.3 Packet CRC

The packet CRC shall be a 16-bit CRC word calculated on the packet header and the packet data field. It shall be generated according to the procedure defined in annex E. The generation shall be based on the polynomial $G(x) = x^{16} + x^{12} + x^5 + 1$ (ITU-T Recommendation X.25 [6]).

At the beginning of each CRC word calculation, all shift register stage contents shall be initialized to "1". The CRC word shall be complemented (1's complement) prior to transmission.

5.3.3 Packet mode - data group level

Service component data content can be structured into MSC data groups for transport in one or more packets. An MSC data group shall contain a data group header, an optional session header, a data group data field and an optional data group CRC. The structure of the MSC data group is shown in figure 9.

NOTE: MSC data groups can also be used to transport data in the PAD part of an MSC stream audio sub-channel.

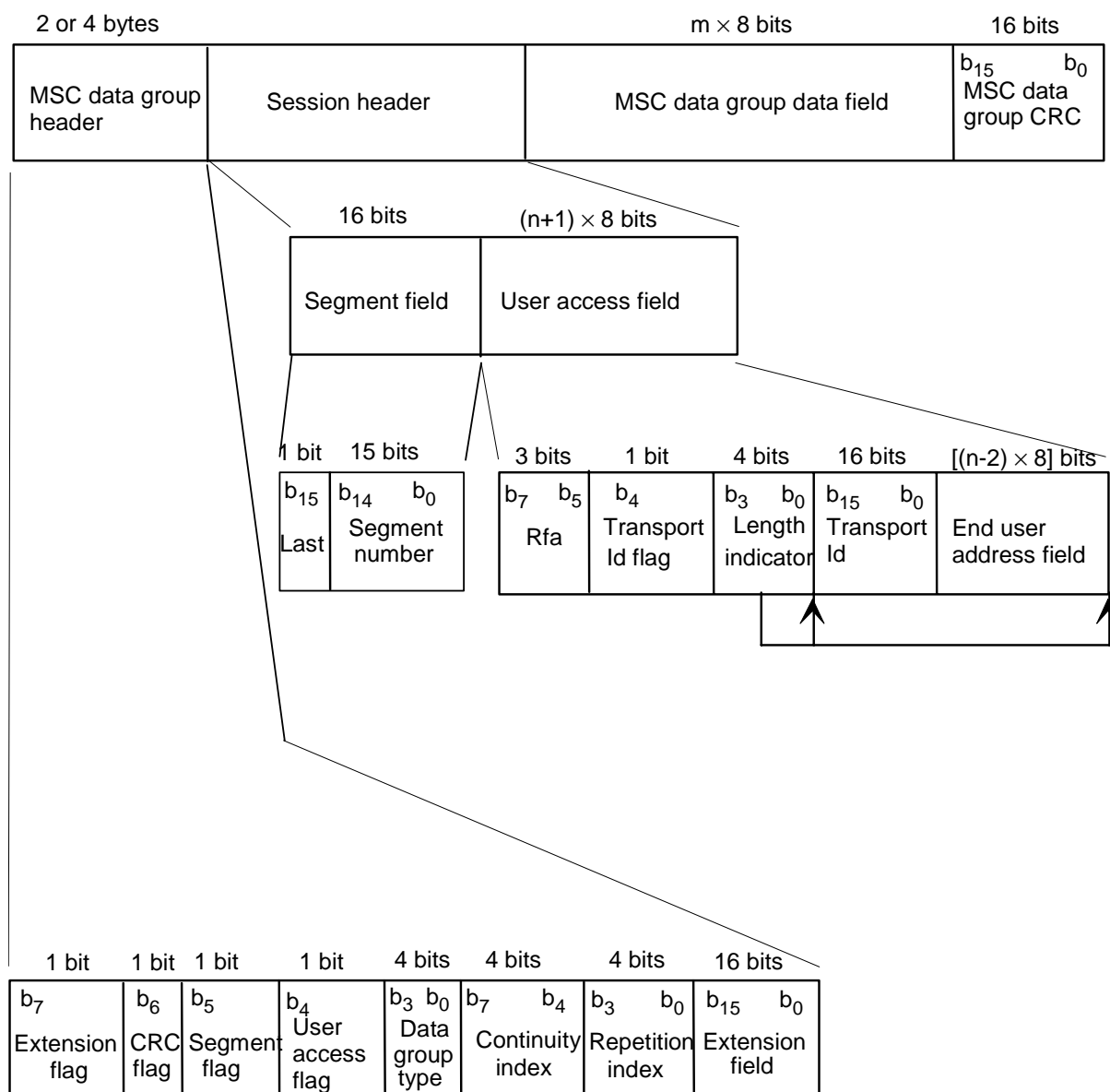


Figure 9: Structure of the MSC data group

5.3.3.1 MSC data group header

The following definitions apply:

- Extension flag:** this 1-bit flag shall indicate whether the extension field is present, or not, as follows:
 - 0: no extension;
 - 1: extension.
- CRC flag:** this 1-bit flag shall indicate whether there is a CRC at the end of the MSC data group as follows:
 - 0: no data group CRC;
 - 1: data group CRC present.
- Segment flag:** this 1-bit flag shall indicate whether the segment field is present, or not, as follows:
 - 0: no segment field;
 - 1: segment field present.

- **User access flag:** this 1-bit flag shall indicate whether the user access field is present, or not, as follows:
 - 0: no user access field;
 - 1: user access field present.
- **Data group type:** this 4-bit field shall define the type of data carried in the data group data field. The following types are defined for use by all data service components:
 - $b_3 - b_0$
 - 0 0 0 0 : General data;
 - 0 0 0 1 : CA messages (see TS 102 367 [15]);

The remaining types are dependant upon the value of the DSCTy and defined by the relevant document (see clause 6.3.1).

- **Continuity index:** the binary value of this 4-bit field shall be incremented each time a MSC data group of a particular type, with a content different from that of the immediately preceding data group of the same type, is transmitted.
- **Repetition index:** the binary value of this 4-bit field shall signal the remaining number of repetitions of a MSC data group with the same data content, occurring in successive MSC data groups of the same type. Exceptionally, the code "1111" shall be used to signal that the repetition continues for an undefined period.
- **Extension field:** this 16-bit field shall be used to carry information for CA on data group level (see TS 102 367 [15]). For other Data group types, the Extension field is reserved for future additions to the Data group header.

5.3.3.2 Session header

- **Last:** this 1-bit flag shall indicate whether the segment number field is the last or whether there are more to be transmitted, as follows:
 - 0: more segments to follow;
 - 1: last segment.
- **Segment number:** this 15-bit field, coded as an unsigned binary number (in the range 0 to 32 767), shall indicate the segment number.

NOTE: The first segment is numbered 0 and the segment number is incremented by one at each new segment.

- User access field:
 - **Rfa (Reserved for future addition):** this 3-bit field shall be reserved for future additions.
 - **Transport Id flag:** this 1-bit flag shall indicate whether the Transport Id field is present, or not, as follows:
 - 0: no Transport Id field;
 - 1: Transport Id field present.
 - **Length indicator:** this 4-bit field, coded as an unsigned binary number (in the range 0 to 15), shall indicate the length n in bytes of the Transport Id and End user address fields.
 - **Transport Id (Identifier):** this 16-bit field shall uniquely identify one data object (file and header information) from a stream of such objects, It may be used to indicate the object to which the information carried in the data group belongs or relates.
 - **End user address field:** this field shall indicate the address of the end user.

5.3.3.3 MSC data group data field

The data group data field shall contain an integral number of bytes, with a maximum of 8 191 bytes.

5.3.3.4 MSC data group CRC

The data group CRC shall be a 16-bit CRC word calculated on the data group header, the session header and the data group data field and generated according to the procedure defined in annex E. The generation shall be based on the polynomial $G(x) = x^{16} + x^{12} + x^5 + 1$ (ITU-T Recommendation X.25 [6]).

At the beginning of each CRC word calculation, all shift register stage contents shall be initialized to "1". The CRC word shall be complemented (1's complement) prior to transmission.

5.3.4 Interrelation of network and transport level in packet mode

The information associated with one MSC data group shall be transmitted in one or more packets, sharing the same address. All packets may contain padding bytes. Figure 10 shows the situation when a MSC data group is spread across several packets, sharing the same address j . The settings of the First/Last flags are given.

The data field of the first packet shall begin with the data group header. The data field of the last packet shall end with the data group CRC, if any, and padding bytes, if necessary.

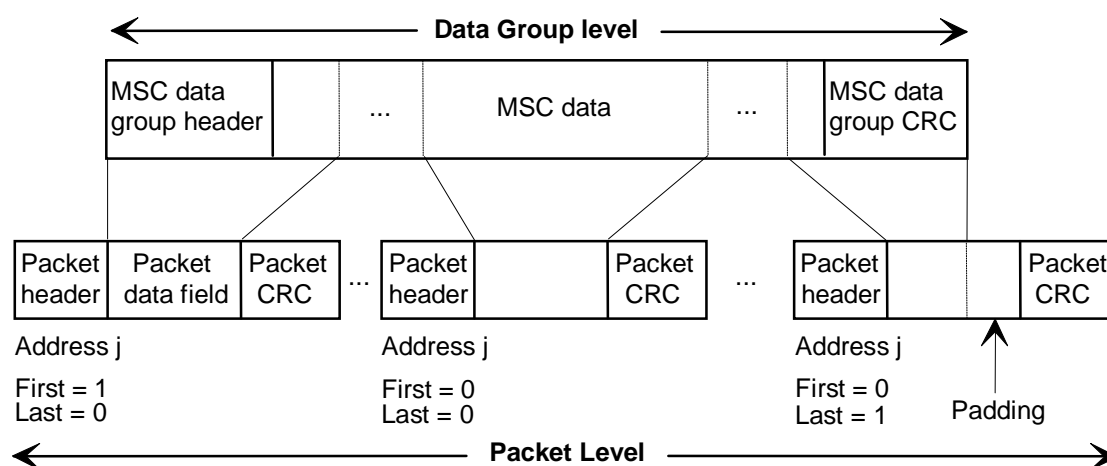


Figure 10: Relationship between a MSC data group and a sequence of packets

5.3.5 FEC for MSC packet mode

Forward Error Correction, in the form of Reed Solomon (RS) outer error protection and outer interleaving, can be applied to sub-channels carrying service components in packet mode in order to further increase the error robustness of DAB data delivery.

The additional error protection is applied in such a way that receivers not equipped with FEC decoders can still recover the packets for the service components, albeit with reduced performance. This is accomplished by creating an FEC frame comprising the unaltered packets and additional RS data calculated over those packets as illustrated in figure 11.

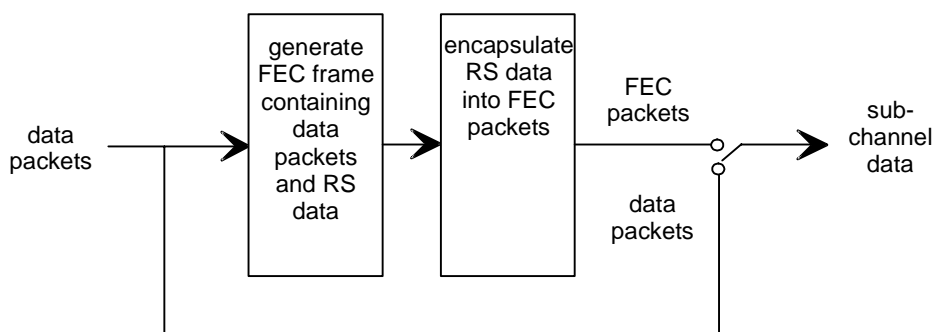


Figure 11: Conceptual diagram of the outer coder and outer interleaver

The input to the functional block is a sequence of packets from a packet multiplexer. This sequence is referred to as the Application Data Packet Set. The Application Data Packet Set may consist of any combination of packet lengths, in any order, which in total comprise exactly 2 256 bytes.

The output of the functional block is the Application Data Packet Set in its original packet order, followed by nine 24-byte FEC packets. The FEC packets contain the RS parity data calculated from the preceding Packet Set. A new Packet Set follows immediately after the nine FEC packets.

The FEC scheme protects all packets in the sub-channel irrespective of their packet address.

A receive terminal applies the reverse process, using the FEC packets to correct any transmission errors in the packets. Terminals that do not implement the FEC scheme may still recover the packets for the selected service component by use of the appropriate packet address and will ignore the FEC packets.

The FEC scheme in use is signalled using FIG 0/14 (see clause 6.2).

5.3.5.1 FEC frame

Figure 12 shows the structure of the FEC frame. The frame has the dimensions of 204 columns by 12 rows and consists of an Application Data Table of 188 columns by 12 rows (i.e. 2 256 bytes) and an RS Data Table of 16 columns by 12 rows (i.e. 192 bytes).

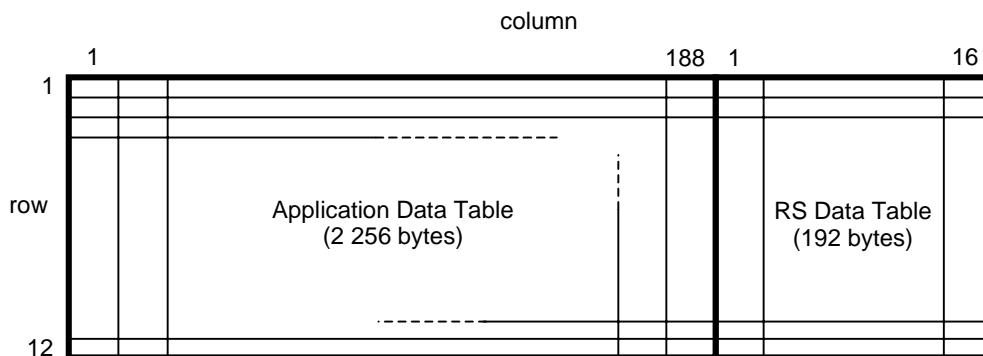


Figure 12: Structure of FEC frame

Packets (as defined in clause 5.3.2) are fed into the Application Data Table column by column starting with the first byte of the first packet going into row 1, column 1 and moving downwards row by row and to the right, column by column. Since there are 12 rows, each 24 byte, 48 byte, 72 byte or 96 byte packet exactly fills 2 columns, 4 columns, 6 columns or 8 columns.

The packet multiplexer shall generate sequences of packets that produce an Application Data Packet Set that completely fills the Application Data Table (i.e. a total of 2 256 bytes).

NOTE 1: Some of the packets may be padding packets.

The RS Data Table is filled by calculating the Reed-Solomon codeword from each row of data. The code used is the Reed-Solomon RS (204,188, t = 8) shortened code (see note 2), derived from the original systematic RS (255,239, t = 8) code.

NOTE 2: The Reed-Solomon codeword has length 204 bytes, dimension 188 bytes and allows up to 8 random erroneous bytes in a received word of 204 bytes to be corrected.

- Code Generator Polynomial: $g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)\dots(x+\lambda^{15})$, where $\lambda = 02_{\text{HEX}}$.
- Field Generator Polynomial: $p(x) = x^8 + x^4 + x^3 + x^2 + 1$.

The shortened Reed-Solomon code may be implemented by adding 51 bytes, all set to zero, before the information bytes (i.e. one row of the Application Data Table) at the input of an RS (255,239, t = 8) encoder. After the RS coding procedure these null bytes shall be discarded, leading to a RS codeword of N = 204 bytes.

For each row number, M, the following applies:

In the generated shortened RS code word for row M, the first byte is taken from column 1 row M of the Application Data Table, the second byte from column 2 row M etc. up to column 188 (inclusive). Similarly, the first calculated RS parity byte, i.e. the 189th byte of the shortened codeword, is inserted in column 1 row M of the RS Data Table, the 190th byte of the codeword in column 2 row M etc. up to column 16 (inclusive) of the RS Data Table. The RS code shortening zeroes can be assumed to be in column - 50, row M to column 0 row M if needed. The end result is that a complete row is identical to the corresponding RS codeword.

5.3.5.2 Transport of RS data

The RS Data Table is transported within nine consecutive FEC packets. The set of FEC packets is transmitted immediately following the Application Data Packet Set used to form the Application Data Table. The structure of the FEC packets is shown in figure 13.

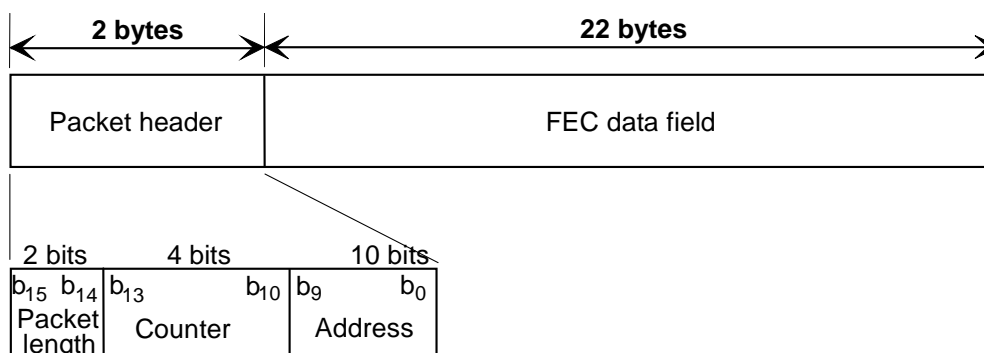


Figure 13: Structure of FEC packet

The packet header has a length of 2 bytes and it shall comprise the following parameters:

- **Packet length:** this 2-bit field shall take the value "00" indicating a 24-byte packet length (see table 4);
- **Counter:** this 4-bit counter, taking the values 0 to 8, shall be incremented by one for each successive FEC packet in a set;
- **Address:** this 10-bit field shall take the binary value "111111110" (1 022).

NOTE: The Packet length and Address parameters occupy the same bit positions in an FEC packet and a packet (see clause 5.3.2) permitting receivers without FEC decoding capability to process (discard) FEC packets.

The 192 bytes of the RS Data Table are transported in the FEC data field of a set of nine consecutive 24-byte FEC packets. The first FEC packet of a set has the Counter field set to 0. Each byte of data in the RS Data Table is mapped into successive FEC data fields, starting with the data byte in row 1, column 1 and working downwards, row by row, and to the right, column by column, until all the data has been mapped. When all the RS data has been mapped, there remain 6 unused bytes at the end of the FEC data field of the ninth FEC packet. These bytes shall be filled with zeros.

The complete set of FEC packets used to transport the RS data is shown in figure 14.

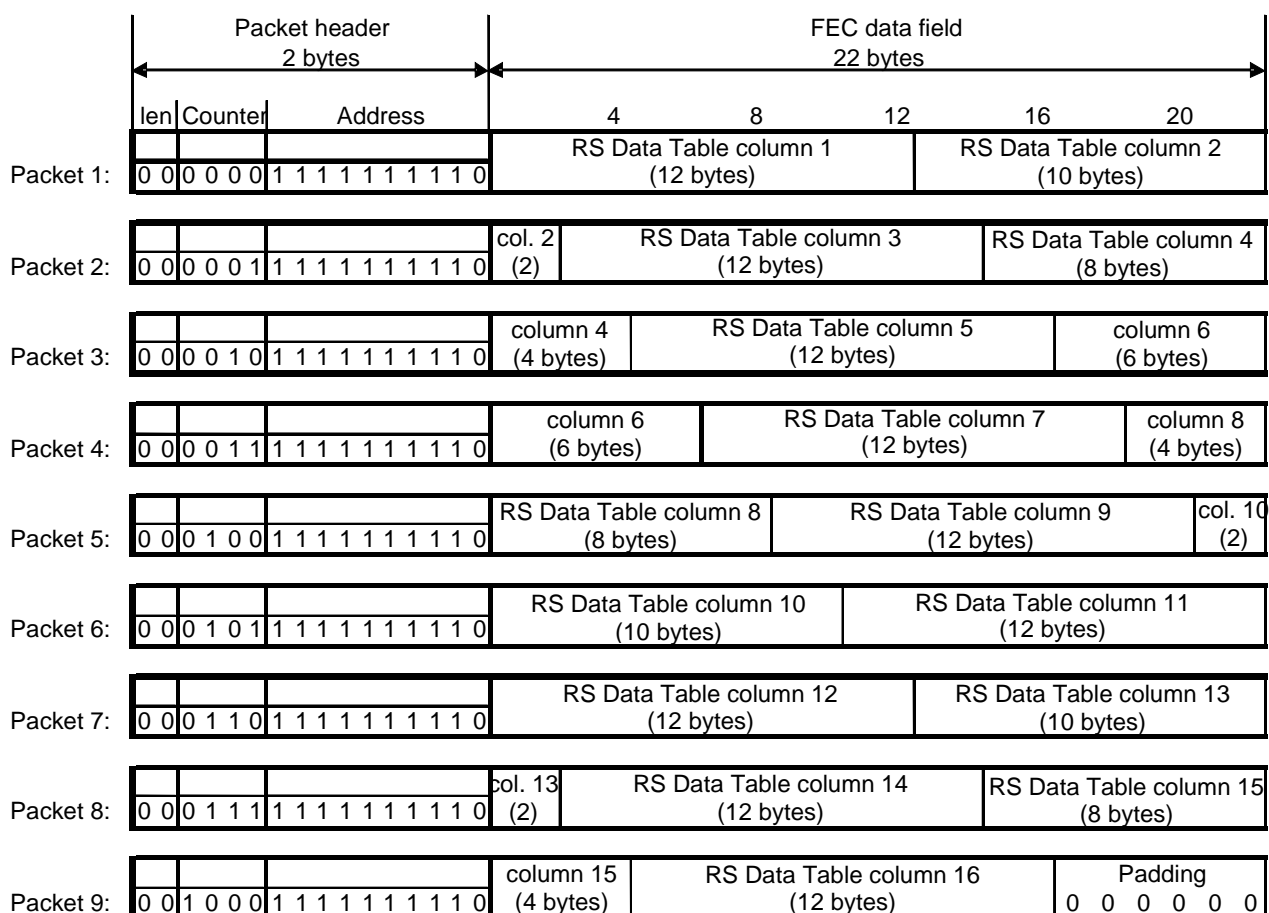


Figure 14: Complete FEC packet set

5.3.5.3 Receiver considerations

The FEC scheme creates a block of data totalling 2 472 bytes, 2 256 bytes from the Application Data Table (the set of packets containing service components) and 216 bytes comprising the RS Data Table transported as nine 24-byte FEC packets. The entire data block must be received and the FEC frame remapped before error correction can take place. The data block may take several logical frames to receive, depending on the data rate of the sub-channel.

A receiver may use the packet CRC to determine if individual packets have been received correctly, and if so, use those packets immediately. The CRC may also be used to inform the FEC decoder about which packets are likely to have errors and which are likely to be error free. More intelligent receivers may use a combination of these techniques to further improve the error-correcting ability of the outer FEC. Receivers that do not implement FEC decoding can still recover packets, but without the improved error performance. In this case, the FEC packets will be decoded as packets and so will, in general, have erroneous CRCs.

5.4 Transport of Service Information in the Auxiliary Information Channel

This clause describes the mechanism for redirecting information from the FIC to the Auxiliary Information Channel (AIC). This mechanism may be used for certain extensions of FIG types 0, 1 and 2 (see clause 8.1.12). The AIC is formed using sub-channel 63 and packet address 1 023. The following conditions shall also apply when the AIC is used:

- the MSC data group (see clause 5.3.3) shall be organized as shown in figure 15. It shall contain FIGs as defined in clause 5.2.2;
- different FIG types may be carried in one MSC data group data field;
- the data group type list in the MSC data group shall be set to "General data";

- the maximum length of the MSC data group data field shall be 512 bytes;
- the MSC data group shall contain a data group CRC.

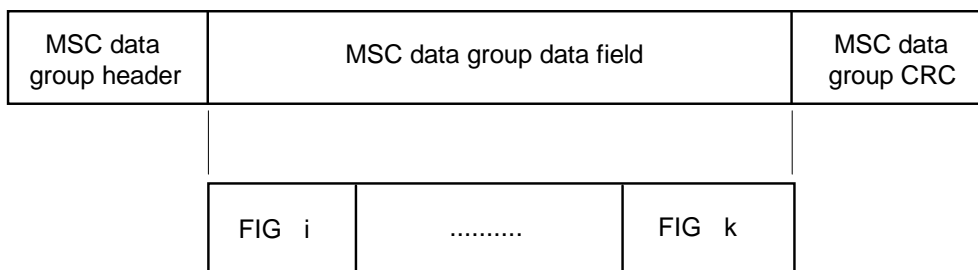


Figure 15: MSC data group structure for carrying FIGs

5.5 Extended labels

Service information labels that require more than 16 bytes to encode the 16 characters may be sent using FIG type 2. In this case a FIG type 1 label with the same extension using the character set "Complete EBU Latin based repertoire" (see TS 101 756 [16]) shall also be sent to provide compatibility with basic receivers.

FIG type 2 permits labels to be signalled with up to 64 bytes using UTF-8 encoding or up to 32 bytes using UCS-2 encoding. In addition, additional characters that are not part of ISO 10646 [20] can be defined.

5.5.1 Structure of the extended label data field

The data field for the label or character definition can be longer than will fit into a single FIB. Segmentation is used to transport the label or character definition in up to eight FIGs. The segments are recombined in the receiver to form the complete label or character definition using the segment index (see clause 5.2.2.2). The total number of segments used to transport the label or character definition is signalled using the segment count field.

The structure of the extended label data field is shown in figure 16.

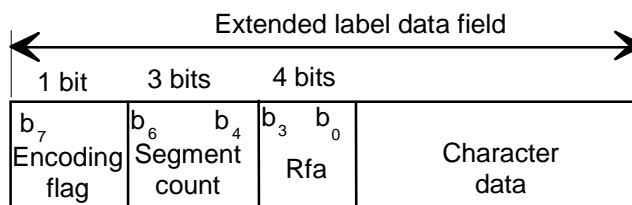


Figure 16: Structure of the extended label data field

The following definitions apply:

Encoding flag: this 1-bit flag shall define the character encoding as follows:

0: UTF-8 character encoding is used (1 to 4 bytes per character);

1: UCS-2 character encoding is used (2 bytes per character, Basic Multilingual Plane).

Segment count: this 3-bit field, expressed as an unsigned binary number in the range 0 to 7, shall define the total number of segments minus 1 used to carry the extended label data field.

Rfa: this 4-bit field shall be reserved for future additions.

Character data: this variable length field shall contain either the label or the character definition, see clauses 5.5.2 and 5.5.3.

5.5.2 Label definition

The FIG type 2 labels are encoded using extensions 0 to 6 (see clause 8.1). The structure of the Character data field which is part of the extended label data field (see also figure 16) for label definition is shown in figure 17.

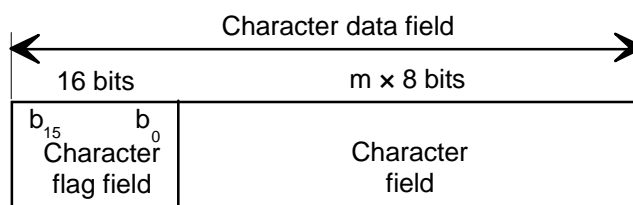


Figure 17: Structure of the character data field for label definition

The following definitions apply:

Character flag field: this 16-bit flag field shall indicate which of the characters of the character field are to be displayed in an abbreviated form of the label, as follows:

b_i : ($i = 0, \dots, 15$);

0: not to be displayed in abbreviated label;

1: to be displayed in abbreviated label.

NOTE: Not more than 8 of the b_i may be set to "1".

If the character field contains less than 16 characters, the unused bits in the character flag field (having no corresponding character) shall be set to zero.

Character field: this variable length field shall define the label. It shall be coded as a string of up to 16 characters, which are encoded according to the Encoding flag (see clause 5.5.1). The first byte is part of the first character.

5.5.3 Character definition

The FIG type 2 character definitions are encoded using Extension 7 of the FIG type 2 (FIG 2/7).

When characters are required for labels that do not have a corresponding ISO 10646 [20] character number, a character number from the "private use zone" of the BMP (0xe000 to 0xf8ff) shall be sent in the Character field of the FIG type 2 label and the corresponding character definition shall be signalled using FIG 2/7. The character definition is valid for all labels signalled in the tuned ensemble.

Characters are defined using a 24×24 pixel grid. The pixels may be clear (white) or set (black). An example of the character definition is shown in figure 18.

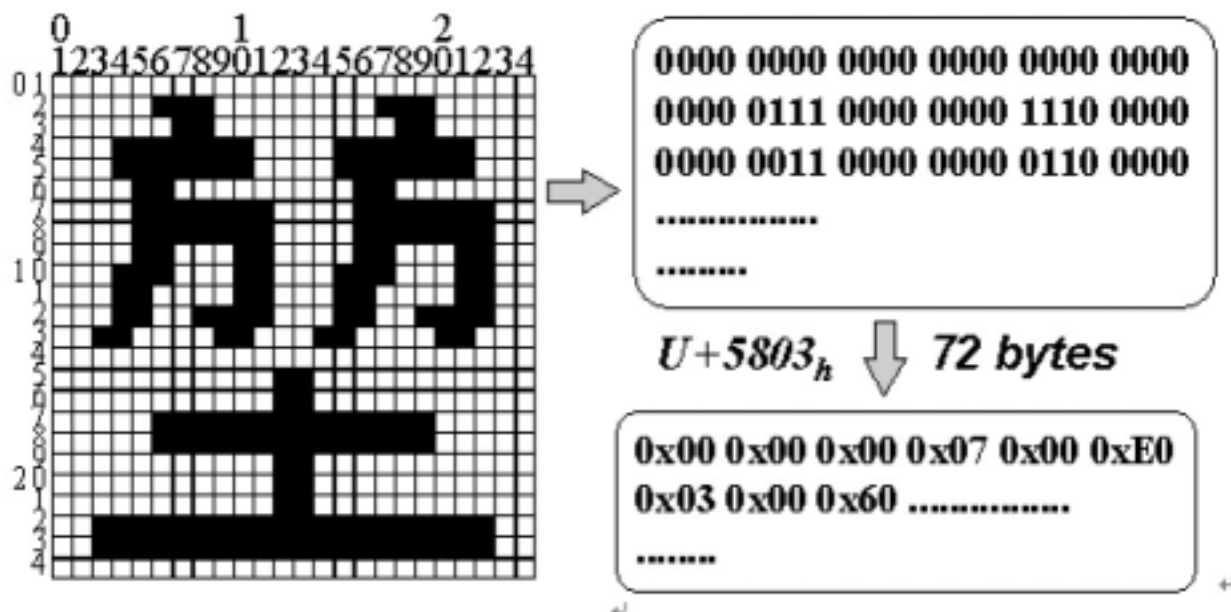


Figure 18: Example of character definition

Figure 19 shows the structure of the Identifier field for the character definition which is part of the Type 2 field (see also figure 6).

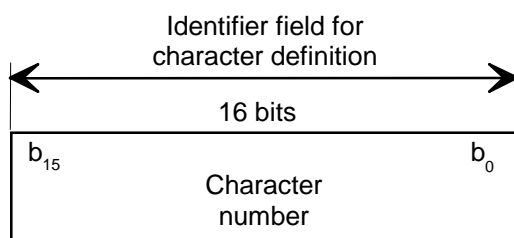


Figure 19: Structure of the Identifier field for the character definition

The following definitions apply:

Character number: this 16-bit field shall identify the Character number from the "private use zone" of the BMP (0xe000 to 0xf7ff) for the character definition.

The structure of the Character data field which is part of the extended label data field (see also figure 16) for character definition is shown in figure 20.

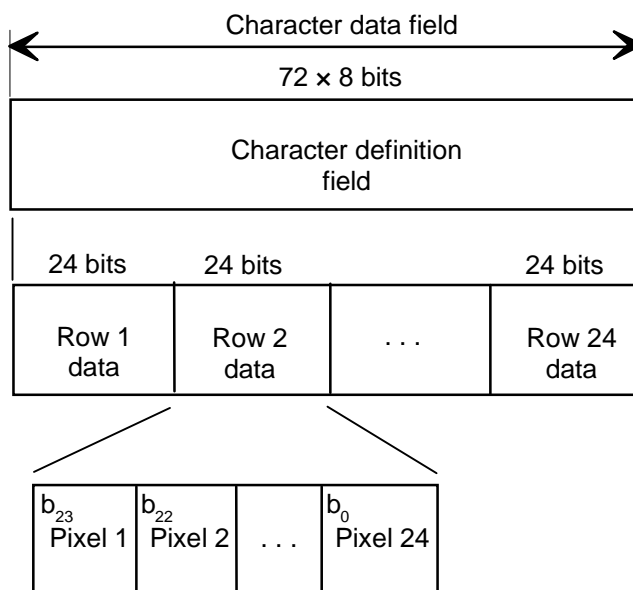


Figure 20: Structure of character data field for character definition

The following definitions apply:

Character definition field: This 72-byte field shall contain the bitmap data for the character. The bitmap is coded as 24 rows of data. The first row, Row 1, corresponds to the top row of the character.

Row n : This 24-bit field shall contain the bitmap data for the row. The bitmap is coded as 24 pixels of data. The first pixel, Pixel 1, corresponds to the left-hand pixel of the row.

Pixel m : This 1-bit field shall contain the state of the pixel as follows:

b_m : ($m = 1, \dots, 24$);

0: the pixel is clear (white);

1: the pixel is set (black).

5.5.4 Segmentation

The complete extended label data field is divided into up to eight segments for transportation in the FIC. The length of each segment is determined from the FIG type 2 header field.

The first byte of the FIG type 2 extended label data field shall be transported in the first segment with corresponding Segment index field equal to 0. Subsequent segments shall be carried in following FIG type 2 data fields with the same Extension and Identifier fields and the Segment index field shall be incremented by 1 for each segment.

5.5.5 Receiver considerations

Receivers with limited display capabilities can display the FIG type 1 labels. Receivers with a greater character repertoire should display the FIG type 2 labels, providing that only 1 or 2 characters from the label cannot be displayed. This may be due to limited character bitmaps or not supporting definable characters signalled using FIG 2/7. The missing characters should be replaced by spaces or a query character.

6 Multiplex Configuration Information (MCI)

6.1 Introduction

The principal method of user access to the service components carried in the Multiplex is by selecting a service. Several services may be accessible within one ensemble, and each service contains one or more service components. However, dedicated DAB data terminals may search for and select the User Application(s) they are able to process automatically or after user selection.

The essential service component of a service is called the primary service component. Normally this would carry the audio (programme service component), but data service components can be primary as well. All other service components are optional and are called secondary service components.

An example of a service structure is shown in figure 21. In this example, the DAB ensemble is recognized by the associated ensemble label ("DAB ENSEMBLE ONE") and carries several services which can be accessed directly by the user. Three of these services are described.

The first service (identified by the service label "ALPHA 1 RADIO") comprises two service components: a primary programme service component and a secondary data component which is used for a Traffic Message Channel (ALPHA-TMC). The programme service component is carried in a sub-channel in the Main Service Channel, whereas the TMC data service component is carried in the Fast Information Data Channel (FIDC) (see clause 8.2) within the FIC.

The second service (identified by the service label "BETA RADIO") comprises two service components. In this case, there is both a primary and a secondary programme service component.

The linking arrangement allows service components to be shared by different services. It also allows the service structure to be changed so that a service may change its service component. The third service (identified by the service label "ALPHA 2 RADIO") shares the ALPHA-TMC data service component with "ALPHA 1 RADIO". Also, at times, it shares the programme service component with "ALPHA 1 RADIO", as indicated by the switch.

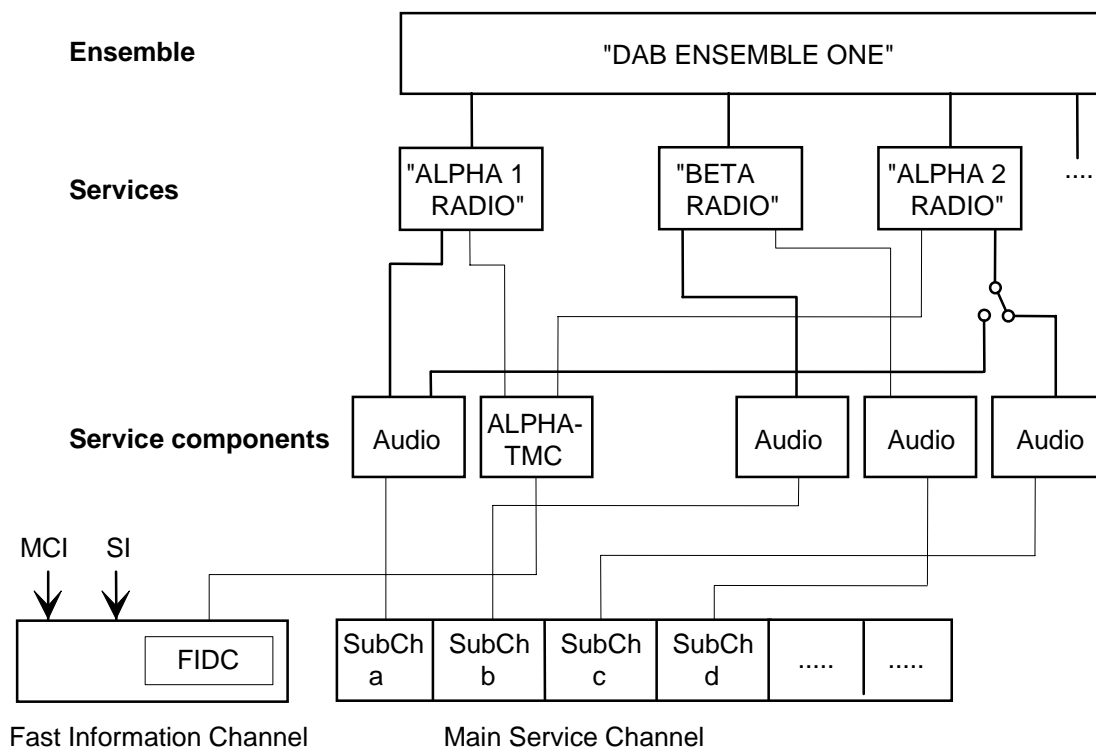


Figure 21: An example of the DAB service structure

The organization of the sub-channels, services and service components in an ensemble is managed by the MCI. The MCI serves five principal functions:

- a) to define the organization of the sub-channels in terms of their position and size in the CIF and their error protection;
- b) to list the services available in the ensemble;
- c) to establish the links between service and service components;
- d) to establish the links between service components and sub-channels or FIDC;
- e) to signal a multiplex re-configuration.

The details of coding the MCI in the FIC are described in clauses 6.2 to 6.4. The dynamic re-configuration of the multiplex is described in clause 6.5.

The MCI is coded in FIG type 0 (see clause 5.2.2.1) using Extensions 0, 1, 2, 3, 4, 8 and 14. The C/N flag is used in Extensions 1, 2, 3, 4, 8 and 14 to distinguish between the current and a future configuration. Extensions 0, 1, 2, 3, 4 and 14 shall be carried in the first FIB of successive 24 ms periods, corresponding to CIFs. Additionally, the first FIB of successive 24 ms periods may carry SI and FIDC content. MCI may also be repeated in other FIBs.

6.2 Sub-channel organization

The sub-channel organization defines the position and size of the sub-channels in the CIF and the error protection employed. It is coded in Extensions 1 and 14 of FIG type 0. Up to 64 sub-channels may be addressed in a multiplex using a sub-channel Identifier which takes values 0 to 63. The values are not related to the sub-channel position in the MSC. The basic sub-channel organization information is coded in FIG 0/1 (see clause 6.2.1). Sub-channels used for carrying packet mode service components can apply additional error protection (see clause 5.3.5) which is signalled using FIG 0/14 (see clause 6.2.2).

6.2.1 Basic sub-channel organization

The Extension 1 of FIG type 0 (FIG 0/1) defines the basic sub-channel organization. Each sub-channel is described explicitly by its start address (in the range 0 to 863 CUs) and (either explicitly or implicitly) by the size of the sub-channel and the error coding protection mechanism employed. The structure is shown in figure 22.

Two forms of signalling the sub-channel size and error protection are used. The first is a shorter form which is used for service components employing the Unequal Error Protection (UEP) profiles given in clause 11.3.1. In this case, the UEP index is signalled explicitly and the sub-channel size can be implicitly derived from it. The second form requires the sub-channel size and error protection to be signalled explicitly. In this case, eight options for defining these parameters are allowed; only the first two are defined and are used for Equal Error Protection (EEP) according to clause 11.3.2.

UEP profiles are designed for audio at bit-rates indicated in table 6, but the use of UEP profiles for other applications is not excluded. EEP profiles may be used for audio as well as for data (see also clauses 11.3.1 and 11.3.2). In particular, UEP profiles are not defined for audio bit-rates 8 kbit/s, 16 kbit/s, 24 kbit/s, 40 kbit/s and 144 kbit/s. For these audio bit-rates, EEP profiles should be used.

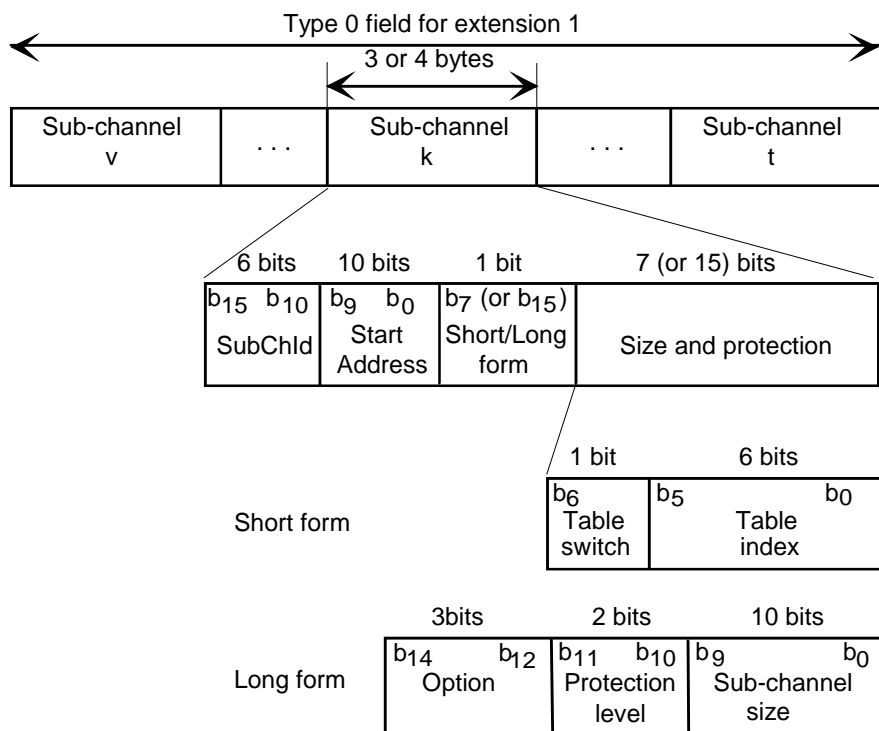


Figure 22: Structure of the sub-channel organization field

The following definitions apply:

SubChId (Sub-channel Identifier): this 6-bit field, coded as an unsigned binary number, shall identify a sub-channel.

Start Address: this 10-bit field, coded as an unsigned binary number (in the range 0 to 863), shall address the first Capacity Unit (CU) of the sub-channel.

Short/Long form: this 1-bit flag shall indicate whether the short or the long form of the size and protection field is used, as follows:

0: short form;

1: long form.

Table 6: Sub-channel size for audio service components as a function of the audio bit rate and the protection level (short-form application)

Index	Sub-channel size (CU)	Protection level	Bit rate (kbit/s)	Index	Sub-channel size (CU)	Protection level	Bit rate (kbit/s)
0	16	5	32	33	64	5	128
1	21	4	32	34	84	4	128
2	24	3	32	35	96	3	128
3	29	2	32	36	116	2	128
4	35	1	32	37	140	1	128
5	24	5	48	38	80	5	160
6	29	4	48	39	104	4	160
7	35	3	48	40	116	3	160
8	42	2	48	41	140	2	160
9	52	1	48	42	168	1	160
10	29	5	56	43	96	5	192
11	35	4	56	44	116	4	192
12	42	3	56	45	140	3	192
13	52	2	56	46	168	2	192
	x			47	208	1	192
14	32	5	64	48	116	5	224
15	42	4	64	49	140	4	224
16	48	3	64	50	168	3	224
17	58	2	64	51	208	2	224
18	70	1	64	52	232	1	224
19	40	5	80	53	128	5	256
20	52	4	80	54	168	4	256
21	58	3	80	55	192	3	256
22	70	2	80	56	232	2	256
23	84	1	80	57	280	1	256
24	48	5	96	58	160	5	320
25	58	4	96	59	208	4	320
26	70	3	96		x		
27	84	2	96	60	280	2	320
28	104	1	96		x		
29	58	5	112	61	192	5	384
30	70	4	112		x		
31	84	3	112	62	280	3	384
32	104	2	112		x		
	x			63	416	1	384

- **Short form:**

- **Table switch:** this 1-bit flag shall indicate whether table 6 is signalled or there is some other use of the table index field, as follows:

0: table 6;

1: reserved for future use of the table index field.

- **Table index:** this 6-bit field, coded as an unsigned binary number, contains an index which shall identify one of the 64 options available for the sub-channel size and protection level. For table 6, the net data rate associated with each index is given. Six of the possible combinations of protection level and rate are not provided and are indicated by an "x".

- **Long form:**

- **Option:** this 3-bit field shall indicate the option used for the long form coding. Two options (000 and 001) are defined to provide Equal Error Protection as defined in clause 11.3.2. The remaining options are reserved for future use.

In the case of option 000, the following parameters are defined (see clause 11.3.2):

- **Protection level:** this 2-bit field shall indicate the protection level as follows:
 - 00: protection level 1-A;
 - 01: protection level 2-A;
 - 10: protection level 3-A;
 - 11: protection level 4-A.

The associated convolutional coding rate is given in table 7.

Table 7: Sub-channel size for data at different coding rates, as a function of the data rate 8 n kbit/s (where n is an integer ≥ 1)

Protection level	1-A	2-A	3-A	4-A
Convolutional coding rate	1/4	3/8	1/2	3/4
Sub-channel size (CUs)	12 n	8 n	6 n	4 n

- **Sub-channel size:** this 10-bit field, coded as an unsigned binary number (in the range 1 to 864), shall define the number of Capacity Units occupied by the sub-channel. Table 7 shows the number of CUs required for all permissible data rates, in multiples of 8 kbit/s, for the four protection levels defined.

In the case of option 001, the following parameters are defined (see clause 11.3.2):

- **Protection level:** this 2-bit field shall indicate the protection level as follows:
 - 00: protection level 1-B;
 - 01: protection level 2-B;
 - 10: protection level 3-B;
 - 11: protection level 4-B.

The associated convolutional coding rate is given in table 8.

- **Sub-channel size:** this 10-bit field, coded as an unsigned binary number (in the range 1 to 864), shall define the number of Capacity Units occupied by the sub-channel. Table 8 shows the number of CUs required for all permissible data rates, in multiples of 32 kbit/s, for the four protection levels defined.

Table 8: Sub-channel size for data at different coding rates, as a function of the data rate 32 n kbit/s (where n is an integer ≥ 1)

Protection level	1-B	2-B	3-B	4-B
Convolutional coding rate	4/9	4/7	4/6	4/5
Sub-channel size (CUs)	27 n	21 n	18 n	15 n

6.2.2 FEC sub-channel organization

The Extension 14 of FIG type 0 (FIG 0/14) defines the additional Forward Error Correcting scheme applied to sub-channels carrying packet mode service components. The structure is shown in figure 23.

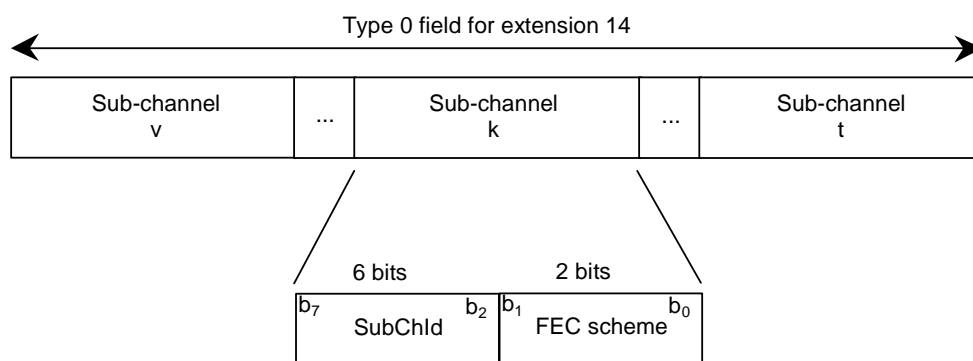


Figure 23: Structure of the FEC sub-channel organization field

The following definitions apply:

SubChId (Sub-channel Identifier): this 6-bit field, coded as an unsigned binary number, shall identify a sub-channel.

FEC Scheme: this 2-bit field shall indicate the Forward Error Correction scheme in use, as follows:

$b_1 - b_0$

- 0 0: no FEC scheme applied;
- 0 1: FEC scheme applied according to clause 5.3.5;
- 1 0: reserved for future definition;
- 1 1: reserved for future definition.

Multiplexes with sub-channels employing additional Forward Error Correction (FEC) for packet mode service components shall signal FIG 0/14 for all sub-channels carrying packet mode service components to indicate which FEC scheme (if any) is applied. It is recommended that FIG 0/14 is included in the MCI signalling of sub-channels carrying packet mode service components even if none are equipped with additional Forward Error Correction (FEC).

6.3 Service organization

The service organization defines the services and service components carried in the ensemble. It is coded in the Extensions 2, 3, 4 and 8 of FIG type 0. Each service shall be identified by a Service Identifier which, when used in conjunction with an Extended Country Code, is unique world-wide. Each service component shall be uniquely identified within the ensemble. When a service component is transported in the MSC in Stream mode, the basic service organization information is coded in FIG 0/2 (see clause 6.3.1). Service components, carried in the Packet mode, require additional signalling of the sub-channel and packet address. Extension 3 is used for this purpose (see clause 6.3.2). Also, when service components are scrambled (see TS 102 367 [15]), the Conditional Access Organization (CAOrg) field (see TS 102 367 [15]) is signalled in Extension 3, for data in packet mode, and in Extension 4 (see clause 6.3.3) for data carried in the stream mode or in the FIC. The Extension 8 provides information to link together the service component description that is valid within the ensemble to a service component description that is valid in other ensembles.

6.3.1 Basic service and service component definition

The Extension 2 of FIG type 0 (FIG 0/2) defines the basic service organization. All the service descriptions applying to a service shall be contained within one field (service k) carried in a single FIG. Figure 24 shows the structure.

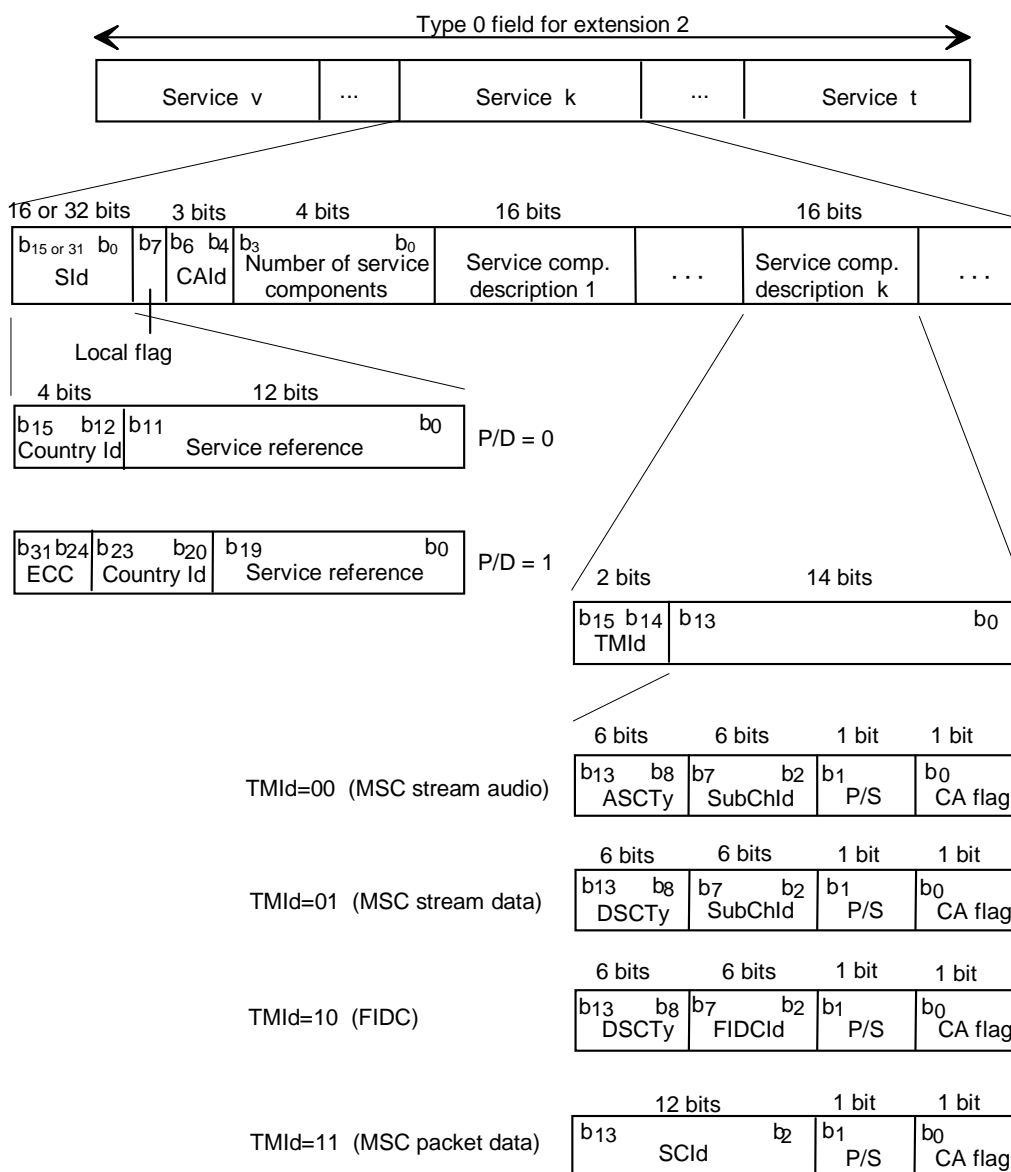


Figure 24: Structure of the service organization field

The following definitions apply:

SId (Service Identifier): this 16-bit or 32-bit field shall identify the service. The length of the SId shall be signalled by the P/D flag, see clause 5.2.2.1.

Service Identifier description:

- **Country Id (Identification):** this 4-bit field shall be as defined in TS 101 756 [16], tables 3 to 7.
- **Service reference:** this field shall indicate the number of the service.
- **ECC (Extended Country Code):** this 8-bit field shall be as defined in TS 101 756 [16], tables 3 to 7.

Local flag: this 1-bit flag shall indicate whether the service is available over the whole, or only a partial area served by the ensemble, as follows:

0: whole ensemble service area;

1: partial ensemble service area.

CAId (Conditional Access Identifier): this 3-bit field shall identify the Access Control System (ACS) used for the service. The definition is given in TS 102 367 [15]. A non-CA capable DAB receiver shall not interpret this field. If no ACS is used for the service, CAId is set to zero.

Number of service components: this 4-bit field, coded as an unsigned binary number, shall indicate the number of service components (maximum 12 for 16-bit SIDs and maximum 11 for 32-bit SIDs), associated with the service. Each component shall be coded, according to the transport mechanism used.

Service component description:

- **TMId (Transport Mechanism Identifier):** this 2-bit field shall indicate the transport mechanism used, as follows:

$b_{15} - b_{14}$

0 0: MSC - Stream mode - audio;

0 1: MSC - Stream mode - data;

1 0: FIDC;

1 1: MSC - Packet mode - data.

- **ASCTy (Audio Service Component Type):** this 6-bit field shall indicate the type of the audio service component. The following types are defined (the remaining types are reserved for future use):

$b_{13} - b_8$

0 0 0 0 0 0: foreground sound (MPEG I or II (Layer II or reserved) coding);

0 0 0 0 0 1: background sound (MPEG I or II (Layer II or reserved) coding);

0 0 0 0 1 0: multi-channel audio extension (MPEG II (Layer II or reserved) coding).

- **SubChId (Sub-channel Identifier):** this 6-bit field shall identify the sub-channel in which the service component is carried.
- **P/S (Primary/Secondary):** this 1-bit flag shall indicate whether the service component is the primary one, as follows:
 - 0: not primary (secondary);
 - 1: primary.
- **CA flag:** this 1-bit field flag shall indicate whether access control applies to the service component, as follows:
 - 0: no access control or access control applies only to a part of the service component;
 - 1: access control applies to the whole of the service component.

Every DAB receiver shall check the "CA flag". A non-CA capable DAB receiver shall not try to decode the service component if the "CA flag" is set to 1.

- **DSCTy (Data Service Component Type):** this 6-bit field shall indicate the type of the data service component. The interpretation of this field shall be as defined in TS 101 756 [16], table 2.

For the FIDC (TMId=10), only entries which have an associated FIG Type 5 coding description shall be permitted - see clause 8.2).

- **FIDCId (Fast Information Data Channel Identifier):** this 6-bit field shall identify the service component carried in the FIDC. It is organized as shown in figure 25 and the TCId and extension fields are described in clause 5.2.2.3.

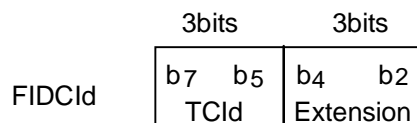


Figure 25: Structure of the FIDCId

- **SCId (Service Component Identifier):** this 12-bit field shall uniquely identify the service component within the ensemble.

6.3.2 Service component in packet mode with or without Conditional Access

The Extension 3 of FIG type 0 (FIG 0/3) gives additional information about the service component description in packet mode. Figure 26 shows the structure.

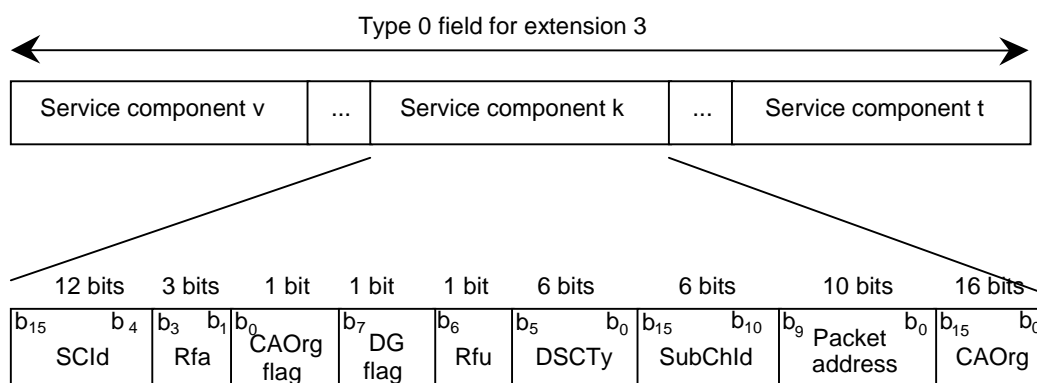


Figure 26: Structure of the service component field in packet mode

The following definitions apply:

SCId (Service Component Identifier): see clause 6.3.1.

Rfa: this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

CAOrg flag: this 1-bit flag shall indicate whether the Conditional Access Organization (CAOrg) field is present, or not, as follows:

0: CAOrg field absent;

1: CAOrg field present.

DG flag: this 1-bit flag shall indicate whether data groups are used to transport the service component as follows:

0: data groups are used to transport the service component;

1: data groups are not used to transport the service component.

Rfu: this 1-bit field shall be reserved for future use of the DSCTy field. The Rfu bit shall be set to zero for the currently specified definition of this field.

DSCTy (Data Service Component Type): see clause 6.3.1.

SubChId (Sub-channel Identifier): see clause 6.3.1.

Packet address: this 10-bit field shall define the address of the packet in which the service component is carried.

CAOrg (Conditional Access Organization): this 16-bit field shall contain information about the applied Conditional Access Systems and mode (see TS 102 367 [15]).

6.3.3 Service component with Conditional Access in stream mode or FIC

The Extension 4 of FIG type 0 (FIG 0/4) gives additional information about the service component description for components with CA and carried in Stream mode or in the FIC. Figure 27 shows the structure.

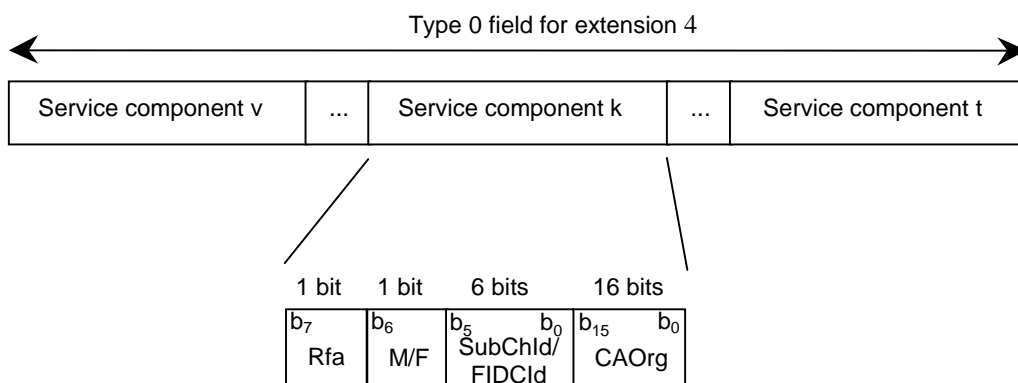


Figure 27: Structure of the service component field in Stream mode or FIC

The following definitions apply:

Rfa: this 1-bit field shall be reserved for future additions. The bit shall be set to zero until it is defined.

M/F: this 1-bit flag shall indicate whether the service component is carried in the MSC or in the FIC and whether the component is identified using the SubChId or the FIDCId, as follows:

0: MSC and SubChId;

1: FIC and FIDCId.

SubChId (Sub-channel Identifier): see clause 6.3.1.

FIDCId (Fast Information Data Channel Identifier): see clause 6.3.1.

CAOrg (Conditional Access Organization): see clause 6.3.2.

6.3.4 Service component "hooks"

For any future service component related SI, table 9 shows how service components can be identified for a particular transport mechanism. The description of these identifiers is given in clause 6.3.1.

Table 9: Service component identifiers

Transport mechanism	Service component identifier
Audio or data in Stream mode	SubChId
FIDC	FIDCId
Data in packets	SCId

6.3.5 Service component global definition

The Extension 8 of FIG type 0 (FIG 0/8) provides information to link together the service component description that is valid within the ensemble to a service component description that is valid in other ensembles. Figure 28 shows the structure.

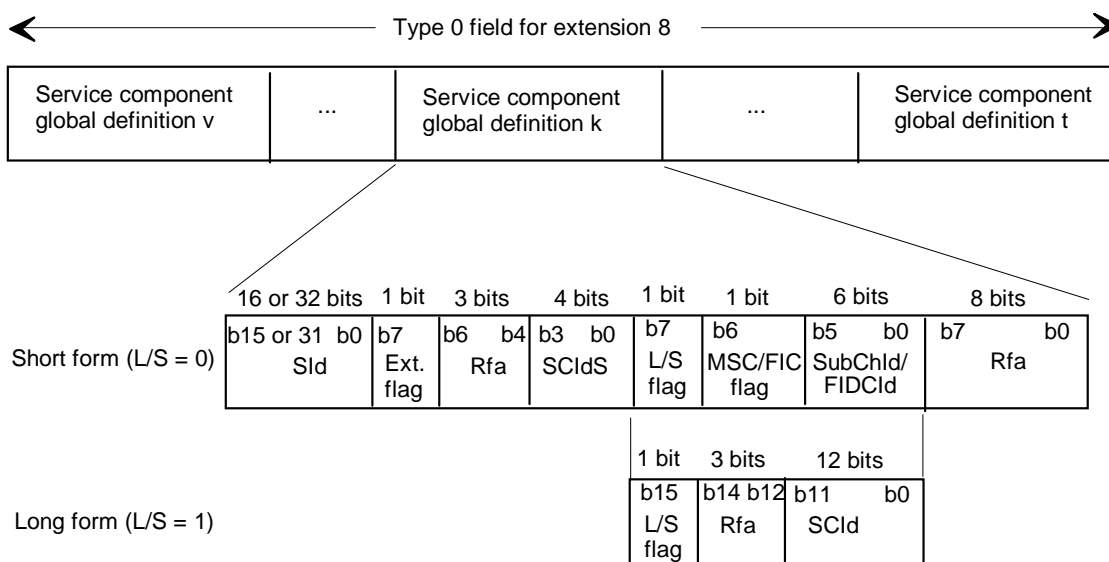


Figure 28: Structure of the service component global definition field

The following definitions apply:

SId (Service Identifier): this 16-bit or 32-bit field shall identify the service. The length of the SId shall be signalled by the P/D flag, see clause 5.2.2.1.

Ext. (Extension) flag: this 1-bit flag shall indicate whether or not the 8-bit Rfa field is present, as follows:

- 0: Rfa field absent;
- 1: Rfa field present.

Rfa: this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

SCIdS (Service Component Identifier within the Service): this 4-bit field shall identify the service component within the service. The combination of the SId and the SCIdS provides a service component identifier which is valid globally.

L/S flag: this 1-bit flag shall indicate whether the service component identifier takes the short or the long form, as follows:

- 0: short form;
- 1: long form.

Short form:

- **MSC/FIC flag:** this 1-bit flag shall indicate whether the component is carried in the MSC in stream mode or in the FIC, and whether the subsequent field contains the SubChId or the FIDCId (see clause 6.3.1), as follows:
 - 0: MSC in stream mode and SubChId identifies the sub-channel;
 - 1: FIC and FIDCId identifies the component.
- **SubChId (Sub-channel Identifier):** this 6-bit field shall identify the sub-channel in which the service component is carried;
- **FIDCId (Fast Information Data Channel Identifier):** this 6-bit flag shall identify the service component carried in the FIDC (see clause 6.3.1);

Long form:

- **Rfa:** this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined;
- **SCId:** this 12-bit field shall identify the service component (see clause 6.3.1).

Rfa: this 8-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

6.4 Ensemble information

The ensemble information contains SI and control mechanisms which are common to all services contained in the ensemble. It is specifically used to provide an alarm flag and CIF counter (24 ms increments) for use with the management of a multiplex re-configuration. Three different levels of multiplex re-configuration are distinguished:

- change of sub-channel organization only (see clause 6.2);
- change of service organization only (see clause 6.3);
- change of sub-channel and service organization.

The ensemble information is coded in Extension 0 of FIG type 0 (FIG 0/0) as shown in figure 29.

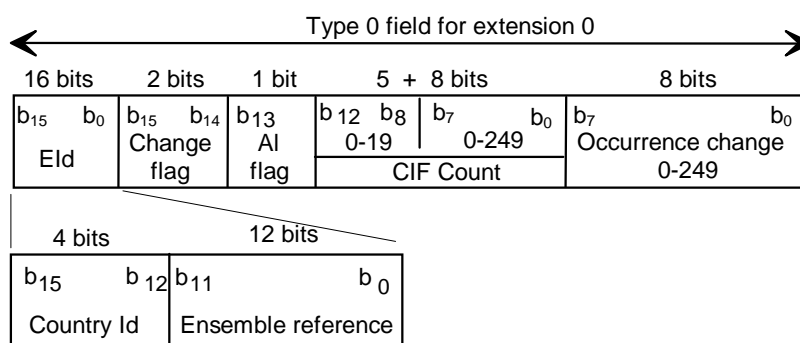


Figure 29: Structure of the ensemble information field

The following definitions apply:

EId (Ensemble Identifier): a unique 16-bit code, shall be allocated to the ensemble and allows unambiguous identification of the ensemble when associated with the Ensemble ECC (see clause 8.1.3).

- Country Id (Country Identification):** see clause 6.3.1.
- Ensemble reference:** this 12-bit field shall indicate the number of the Ensemble allocated for use within a national area.

Change flag: this 2-bit field shall be used to indicate whether there is to be a change in the sub-channel or service organization, or both, as follows:

$b_{15} - b_{14}$

- | | | |
|---|----|--|
| 0 | 0: | no change, no occurrence change field present; |
| 0 | 1: | sub-channel organization only; |
| 1 | 0: | service organization only; |
| 1 | 1: | sub-channel organization and service organization. |

AL flag (Alarm flag): this 1-bit flag shall be used to signal that alarm messages are accessible within the ensemble, as follows:

- | | |
|----|--------------------------------|
| 0: | alarm messages not accessible; |
| 1: | alarm messages accessible. |

The alarm messages are presented as an alarm announcement which interrupts the reception of programme services carried in the ensemble (see clause 8.1.6.1).

CIF count: this modulo-5 000 binary counter shall be arranged in two parts and is incremented by one at each successive CIF. The higher part is a modulo-20 counter (0 to 19) and the lower part is a modulo-250 counter (0 to 249).

Occurrence change: this 8-bit field shall indicate the value of the lower part of the CIF counter from which the new configuration applies.

NOTE: In any 96 ms period, the FIG 0/0 should be transmitted in a fixed time position. In transmission mode I, this should be the first FIB (of the three) associated with the first CIF (of the four) in the transmission frame (see clause 5.1). In transmission modes II and III, this should be the first FIB of every fourth transmission frame. In transmission mode IV, this should be the first FIB (of the three) associated with the first CIF (of the two) in every alternate transmission frame (see clause 5.1).

6.5 Multiplex re-configuration

The ensemble information (see clause 6.4) provides the required mechanisms for changing the multiplex configuration whilst maintaining continuity of services. Such a multiplex re-configuration is achieved by sending at least the relevant part of the MCI of the future multiplex configuration in advance as well as the MCI for the current configuration. When the sub-channel organization changes, the relevant part of the MCI is that encoded in FIG 0/1 and, for sub-channels applying additional FEC for packet mode, FIG 0/14. When the service organization changes, the relevant part of the MCI is that encoded in FIG 0/2, FIG 0/3, FIG 0/4, and FIG 0/8. Accordingly, every MCI message includes a C/N flag signalling whether its information applies to the current or to the next multiplex configuration (see clause 5.2.2).

Service continuity requires the signalling of the exact instant of time, from which a multiplex re-configuration is to be effective. The time boundary between two CIFs is used for this purpose. Every CIF is addressable by the value of the CIF counter. The occurrence change field, which comprises the lower part of the CIF count, is used to signal the instant of the multiplex re-configuration. It permits a multiplex re-configuration to be signalled within an interval of up to six seconds in advance. A multiplex configuration shall remain stable for at least six seconds (250 CIFs).

NOTE: It is expected that the MCI for a new configuration will be signalled at least three times in the six-second period immediately before the change occurs.

A multiplex re-configuration requires a careful co-ordination of the factors which affect the definition of the sub-channels. These factors include the source Audio/Data (A/D) bit rate and convolutional encoding/decoding. The timing of changes made to any of these factors can only be made in terms of logical frames. However the logical frame count is related to the CIF count (see clause 5.3) and this provides the link for co-ordinating these activities.

In general, whenever a multiplex re-configuration occurs at a given CIF count n (i.e. the new configuration is valid from this time), then each of the actions related to the sub-channels, affected by this re-configuration, shall be changed at the logical frame with the corresponding logical frame count. There is only one exception to this rule: if the number of CUs allocated to a sub-channel decreases at the CIF count n , then all the corresponding changes made in that sub-channel, at the logical frame level, shall occur at CIF count $(n - 15)$ which is fifteen 24 ms bursts in advance. This is a consequence of the time interleaving process, described in clause 12.

Additional information related to multiplex re-configuration is given in annex D.

7 Audio coding

The coding technique for high quality audio signals uses the properties of human sound perception by exploiting the spectral and temporal masking effects of the ear. This technique allows a bit rate reduction from 768 kbit/s down to about 100 kbit/s per mono channel, while preserving the subjective quality of the digital studio signal for any critical source material (see reference ITU-R Recommendation BS.1284 [10]).

An overview of the principal functions of the audio coding scheme is shown in the simplified block diagram of the DAB audio encoder (see figure 30). The main characteristics of the audio coding system, like audio modes, bit rates and audio frame length are given in clause A.2, whereas the characteristics of the input audio signal are given in clause A.1.

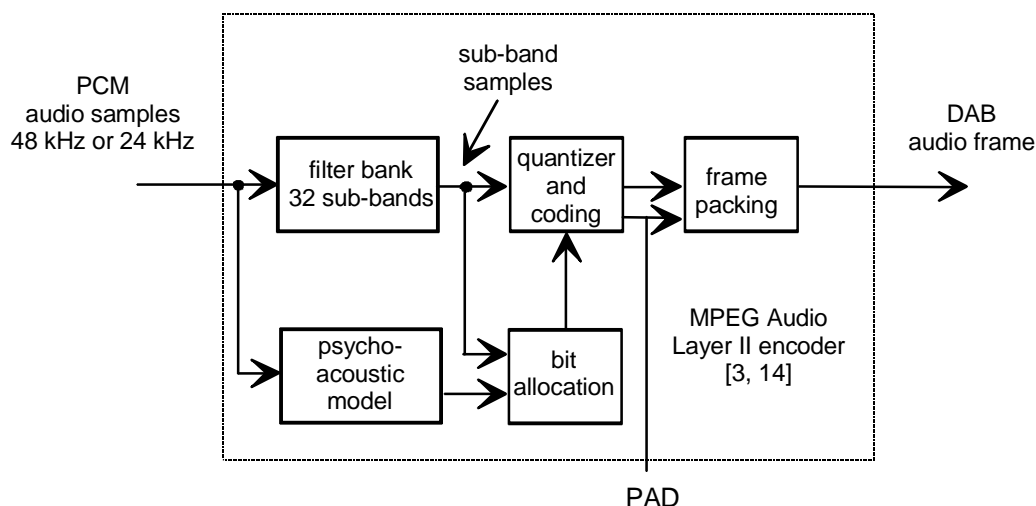


Figure 30: Simplified block diagram of the DAB audio encoder

The input PCM audio samples are fed into the audio encoder. A filter bank creates a filtered and sub-sampled representation of the input audio signal. The filtered samples are called sub-band samples. A psychoacoustic model of the human ear should create a set of data to control the quantizer and coding. These data can be different depending on the actual implementation of the encoder. An estimation of the masking threshold can be used to obtain these quantizer control data. The quantizer and coding block shall create a set of coding symbols from the sub-band samples. The frame packing block shall assemble the actual audio bit stream from the output data of the previous block, and shall add other information, such as header information, CRC words for error detection and Programme Associated Data (PAD), which are intimately related with the coded audio signal. For a sampling frequency of 48 kHz, the resulting audio frame corresponds to 24 ms duration of audio and shall comply with the Layer II format, ISO/IEC 11172-3 [3]. The audio frame shall map on to the logical frame structure in such a way that the first bit of the DAB audio frame corresponds to the first bit of a logical frame. For a sampling frequency of 24 kHz, the resulting audio frame corresponds to 48 ms duration of audio and shall comply with the Layer II LSF format, ISO/IEC 13818-3 [11]. The audio frame shall map on to the logical frame structure in such a way that the first bit of the DAB audio frame corresponds to the first bit of a logical frame (this may be associated with either an "even" or an "odd" logical frame count). The formatting of the DAB audio frame shall be done in such a way that the structure of the DAB audio frame conforms to the audio bit stream syntax described in clause 7.3.

The simplified block diagram of the audio decoder in the receiver, shown in figure 31, accepts the DAB audio frame in the syntax defined in clause 7.3.2 which is a conformant subset of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) bit stream syntax defined in clause 7.3.1. This allows the use of an MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) decoder. The DAB audio frame shall be fed into the audio decoder, which unpacks the data of the frame to recover the various elements of information. The reconstruction block shall reconstruct the quantized sub-band samples. An inverse filter bank shall transform the sub-band samples back to produce digital PCM audio signals in the case of ISO/IEC 11172-3 [3] at 48 kHz sampling frequency and in the case of ISO/IEC 13818-3 [11] at 24 kHz according to annex B.

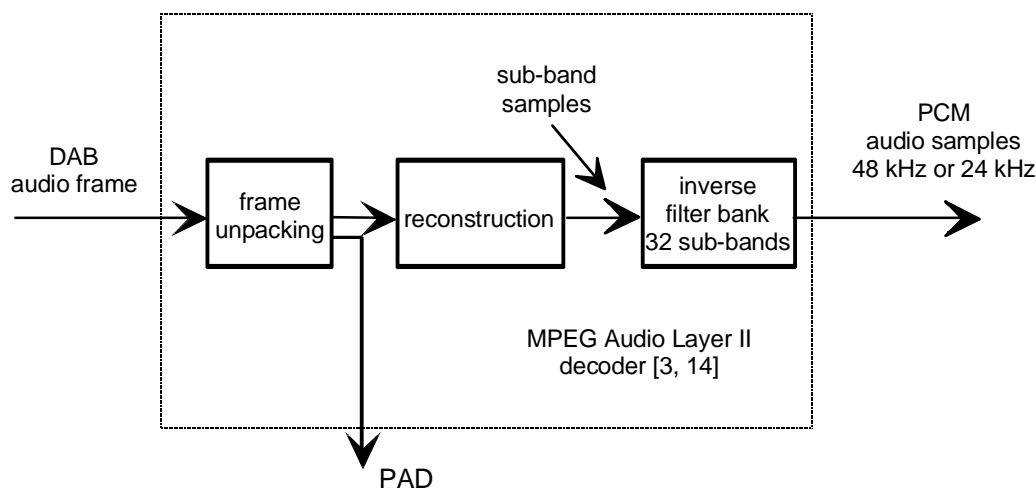


Figure 31: Simplified block diagram of the DAB audio decoder

7.1 Audio encoding

The source encoder for the DAB system is the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) encoder with restrictions on some parameters and some additional protection against transmission errors. In the ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11] International Standards only the encoded audio bit stream, rather than the encoder, and the decoder are specified. In subsequent clauses, both normative and informative parts of the encoding technique are described. An example of one complete suitable encoder with the corresponding flow diagram (figure 32) is given in the following clauses.

The DAB source coding algorithm is based on a perceptual coding technique. The six primary parts of such an audio encoding technique are:

- 1) analysis sub-band filter (clauses 7.1.1 and C.1);
- 2) Scale Factor calculation (clauses 7.1.2 to 7.1.4);
- 3) psychoacoustic model (clauses 7.1.5 and C.2);
- 4) bit allocation procedure (clauses 7.1.6 and C.3);
- 5) quantizing and coding (clauses 7.1.7 and 7.1.8);
- 6) bit stream formatter (clause 7.1.9).

7.1.1 Analysis sub-band filter

An analysis sub-band filter should be used to split the broadband audio signal with sampling frequency f_s into 32 equally spaced sub-bands, each with a sampling frequency of $f_s/32$. This filter, called a poly-phase analysis filter bank, is critically sampled (i.e. there are as many samples in the sub-band domain as there are in the time domain). A detailed description of a suitable analysis sub-band filter bank with the appropriate formulae, coefficients and flow charts is provided in clause C.1.

The encoding algorithm provides a frequency response down to 0 Hz. However, in applications where this is not desirable, a high-pass filter should be included at the audio input of the encoder. The application of such a high-pass filter avoids an unnecessarily high bit rate requirement for the lowest sub-band and may increase the overall audio quality. The cut-off frequency should be in the range of 2 Hz to 10 Hz.

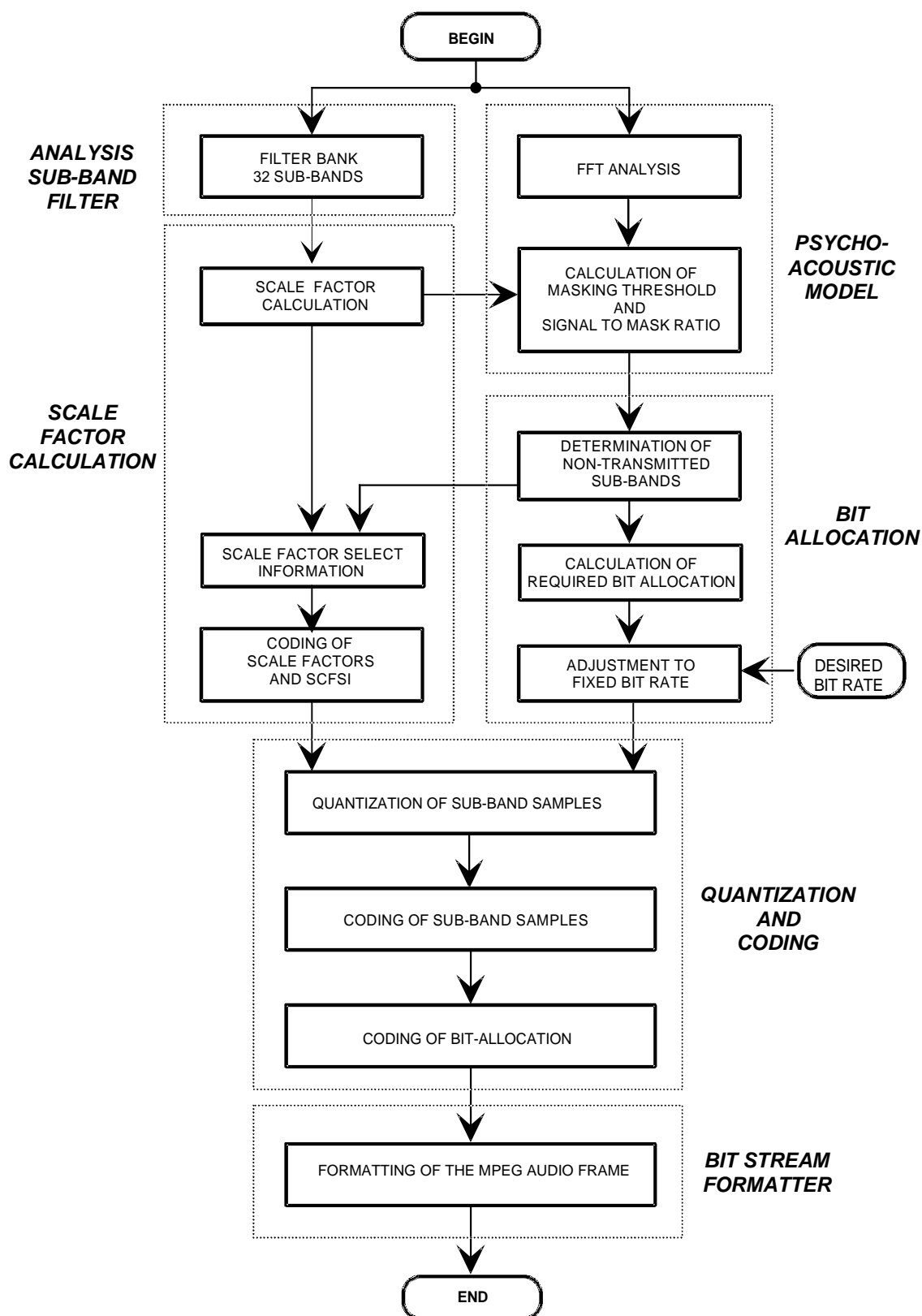


Figure 32: Flow diagram of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) encoder

7.1.2 Scale Factor calculation

In each sub-band, 36 samples shall be grouped for processing. Before quantization, the output samples of the filter bank should be normalized. The calculation of the Scale Factor (ScF) for each sub-band shall be performed every 12 sub-band samples. The maximum of the absolute value of these 12 samples shall be determined. The lowest value, given by the column "Scale Factor" in table 10, which is larger than this maximum shall be used as the ScF of the 12 sub-band samples.

Table 10: Scale Factors

Index iscf	Scale Factor ScF	Index iscf	Scale Factor ScF
0	2,00000000000000	32	0,00123039165029
1	1,58740105196820	33	0,00097656250000
2	1,25992104989487	34	0,00077509816991
3	1,00000000000000	35	0,00061519582514
4	0,79370052598410	36	0,00048828125000
5	0,62996052494744	37	0,00038754908495
6	0,50000000000000	38	0,00030759791257
7	0,39685026299205	39	0,00024414062500
8	0,31498026247372	40	0,00019377454248
9	0,25000000000000	41	0,00015379895629
10	0,19842513149602	42	0,00012207031250
11	0,15749013123686	43	0,00009688727124
12	0,12500000000000	44	0,00007689947814
13	0,09921256574801	45	0,00006103515625
14	0,07874506561843	46	0,00004844363562
15	0,06250000000000	47	0,00003844973907
16	0,04960628287401	48	0,00003051757813
17	0,03937253280921	49	0,00002422181781
18	0,03125000000000	50	0,00001922486954
19	0,02480314143700	51	0,00001525878906
20	0,01968626640461	52	0,00001211090890
21	0,01562500000000	53	0,00000961243477
22	0,01240157071850	54	0,00000762939453
23	0,00984313320230	55	0,00000605545445
24	0,00781250000000	56	0,00000480621738
25	0,00620078535925	57	0,00000381469727
26	0,00492156660115	58	0,00000302772723
27	0,00390625000000	59	0,00000240310869
28	0,00310039267963	60	0,00000190734863
29	0,00246078330058	61	0,00000151386361
30	0,00195312500000	62	0,00000120155435
31	0,00155019633981		

7.1.3 Coding of Scale Factors

This clause is partly of informative, and partly of normative nature. The index "iscf" in table 10 is represented by 6 bits, MSb first. The ScF of a certain sub-band shall be transmitted only if a non-zero number of bits has been allocated to this sub-band.

A DAB audio frame corresponds to 36 sub-band samples and therefore contains three ScFs per sub-band. Some may not be transmitted. This clause gives information about which ScFs should be transmitted, and how they shall be encoded.

The two differences $dscf_1$ and $dscf_2$ of the successive ScF indices $iscf_1$, $iscf_2$ and $iscf_3$ shall be calculated as follows:

- $dscf_1 = iscf_1 - iscf_2$;
- $dscf_2 = iscf_2 - iscf_3$.

Five classes of ScF difference shall be defined. The class of each of the differences should be determined by the following table 11.

Table 11: ScF difference classes

class	dscf
1	$dscf \leq -3$
2	$-3 < dscf < 0$
3	$dscf = 0$
4	$0 < dscf < 3$
5	$dscf \geq 3$

Table 12: ScF transmission patterns

Class ₁	Class ₂	Scale Factors used in Encoder	Transmission Pattern	Scale Factor Select. Information (ScFSI)	Code
1	1	1 2 3	1 2 3	0	00
1	2	1 2 2	1 2	3	11
1	3	1 2 2	1 2	3	11
1	4	1 3 3	1 3	3	11
1	5	1 2 3	1 2 3	0	00
2	1	1 1 3	1 3	1	01
2	2	1 1 1	1	2	10
2	3	1 1 1	1	2	10
2	4	4 4 4	4	2	10
2	5	1 1 3	1 3	1	01
3	1	1 1 1	1	2	10
3	2	1 1 1	1	2	10
3	3	1 1 1	1	2	10
3	4	3 3 3	3	2	10
3	5	1 1 3	1 3	1	01
4	1	2 2 2	2	2	10
4	2	2 2 2	2	2	10
4	3	2 2 2	2	2	10
4	4	3 3 3	3	2	10
4	5	1 2 3	1 2 3	0	00
5	1	1 2 3	1 2 3	0	00
5	2	1 2 2	1 2	3	11
5	3	1 2 2	1 2	3	11
5	4	1 3 3	1 3	3	11
5	5	1 2 3	1 2 3	0	00

The pair of difference classes shall indicate the entry point in the table 12. For each pair of difference classes the actual transmission pattern of Scale Factors and the actual Scale Factor Selection Information (ScFSI) shall be determined from table 12.

Only the Scale Factors indicated in the "transmission pattern" shall be transmitted. A "1", "2" or "3" means that the first, second or third Scale Factor, respectively, is transmitted within an audio frame. A "4" means that the maximum of the three Scale Factors is transmitted. If two or three of the Scale Factors are the same, not all Scale Factors should be transmitted for a certain sub-band within one audio frame. The information describing the number and the position of the Scale Factors in each sub-band is called "Scale Factor Select. Information" (ScFSI).

7.1.4 Coding of Scale Factor Selection Information

The ScFSI shall be coded by an unsigned two bit binary word, MSb first, which is also to be found in the table 12, showing the Scale Factor transmission patterns. Only the ScFSI for the sub-bands which will have a non-zero bit allocation shall be transmitted.

7.1.5 Psychoacoustic model

A psychoacoustic model should calculate a just-noticeable noise-level for each sub-band in the filter bank. This noise level should be used in the bit allocation procedure to determine the actual quantizer for each sub-band. The final output of the model is a Signal-to-Mask Ratio (SMR) for each sub-band. For a high coding efficiency, it is recommended to use a psychoacoustic model with an appropriate frequency analysis. An example of a reference psychoacoustic model is presented in clause C.2.

7.1.6 Bit allocation

A bit allocation procedure shall be applied. Different strategies for allocating the bits to the sub-band samples of the individual sub-bands are possible. A reference model of the bit allocation procedure is described in clause C.3. The principle used in this allocation procedure is minimization of the total noise-to-mask ratio over the audio frame with the constraint that the number of bits used does not exceed the number of bits available for that DAB audio frame. The allocation procedure should consider both the output samples from the filter bank and the Signal-to-Mask-Ratios (SMRs) from the psychoacoustic model. The procedure should assign a number of bits to each sample (or group of samples) in each sub-band, in order to simultaneously meet both the bit rate and masking requirements. At low bit rates, when the demand derived from the masking threshold cannot be met, the allocation procedure should attempt to spread bits in a psychoacoustically inoffensive manner among the sub-bands.

After determining, how many bits should be distributed to each sub-band signal, the resulting number shall be used to code the sub-band samples, the ScFSI and the ScFs. Only a limited number of quantizations is allowed for each sub-band.

In the case of 48 kHz sampling frequency tables 14 and 15 indicate for every sub-band the number of quantization steps which shall be used to quantize the sub-band samples. Table 13 shall be used for bit rates of 56 kbit/s to 192 kbit/s in single channel mode as well as for 112 kbit/s to 384 kbit/s in all other audio modes. The number of the lowest sub-band for which no bits are allocated, called "sblimit", equals 27, and the total number of bits used for the bit allocation per audio frame is defined by the sum of "nbal". If "sblimit" is equal to 27, the sum of "nbal" is equal to 88 for single channel mode, whereas the sum of "nbal" is equal to 176 for dual channel or stereo mode. This number is smaller, if the joint stereo mode is used. Table 14 shall be used for bit rates of 32 kbit/s and 48 kbit/s in single channel mode, as well as for 64 kbit/s and 96 kbit/s in all other audio modes. In this case "sblimit" is equal to 8, and the total number of bits used for the bit allocation per audio frame, i.e. sum of "nbal" is equal to 26 for single channel mode, whereas the sum of "nbal" is equal to 52 for dual channel or stereo mode. This number is 40, if joint stereo mode with mode_extension "00" is used.

In the case of 24 kHz sampling frequency, table 15 indicates for every sub-band the number of quantization steps which shall be used to quantize the sub-band samples. Other than in the case of 48 kHz sampling frequency, table 15 shall be used for all bit rates which are specified for MPEG-2 Audio Layer II ISO/IEC 13818-3 [11] low sampling frequency coding, in the range of 8 kbit/s to 160 kbit/s, independent of the audio mode.

The number of the lowest sub-band for which no bits are allocated, called "sblimit", equals 30, and the total number of bits used for the bit allocation per audio frame is defined by the sum of "nbal". The sum of "nbal" is equal to 75 for single channel mode, whereas the sum of "nbal" is equal to 150 for dual channel or stereo mode. This number is smaller, if the joint stereo mode is used.

The number of bits required to represent these quantized sub-band samples shall be derived from the last two columns of table 17.

7.1.7 Bit allocation coding

In order to increase the coding efficiency, only a limited number of possible quantizations are permitted. Both the number and the quantizations may be different from one sub-band (denoted as "sb" in tables 14 to 16) to another. Only the index with word length "nbal" given in tables 14 to 16, which depends on the bit rate and audio mode, shall be transmitted, MSb first.

Table 13: Bit allocation and possible quantization per sub-band for 48 kHz sampling frequency

Bit rates: 56 kbit/s, 64 kbit/s, 80 kbit/s, 96 kbit/s, 112 kbit/s, 128 kbit/s, 160 kbit/s and 192 kbit/s (single channel mode)																	
Bit rates: 112 kbit/s, 128 kbit/s, 160 kbit/s, 192 kbit/s, 224 kbit/s, 256 kbit/s, 320 kbit/s and 384 kbit/s (all other audio modes)																	
index --->																	
sb	nbal	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		nlevels															
0	4	-	3	7	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383	32 767	65 535
1	4	-	3	7	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383	32 767	65 535
2	4	-	3	7	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383	32 767	65 535
3	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
4	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
5	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
6	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
7	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
8	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
9	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
10	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	65 535
11	3	-	3	5	7	9	15	31	65 535								
12	3	-	3	5	7	9	15	31	65 535								
13	3	-	3	5	7	9	15	31	65 535								
14	3	-	3	5	7	9	15	31	65 535								
15	3	-	3	5	7	9	15	31	65 535								
16	3	-	3	5	7	9	15	31	65 535								
17	3	-	3	5	7	9	15	31	65 535								
18	3	-	3	5	7	9	15	31	65 535								
19	3	-	3	5	7	9	15	31	65 535								
20	3	-	3	5	7	9	15	31	65 535								
21	3	-	3	5	7	9	15	31	65 535								
22	3	-	3	5	7	9	15	31	65 535								
23	2	-	3	5	65 535												
24	2	-	3	5	65 535												
25	2	-	3	5	65 535												
26	2	-	3	5	65 535												
27	0	-															
28	0	-															
29	0	-															
30	0	-															
31	0	-															

Table 14: Bit allocation and possible quantization per sub-band for 48 kHz sampling frequency

Bit rates: 32 kbit/s and 48 kbit/s (single channel mode)																	
Bit rates: 64 kbit/s and 96 kbit/s (all other audio modes)																	
index --->		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
sb	nbal	nlevels															
0	4	-	3	5	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383	32 767
1	4	-	3	5	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383	32 767
2	3	-	3	5	9	15	31	63	127								
3	3	-	3	5	9	15	31	63	127								
4	3	-	3	5	9	15	31	63	127								
5	3	-	3	5	9	15	31	63	127								
6	3	-	3	5	9	15	31	63	127								
7	3	-	3	5	9	15	31	63	127								
8	0	-															
9	0	-															
10	0	-															
11	0	-															
12	0	-															
13	0	-															
14	0	-															
15	0	-															
16	0	-															
17	0	-															
18	0	-															
19	0	-															
20	0	-															
21	0	-															
22	0	-															
23	0	-															
24	0	-															
25	0	-															
26	0	-															
27	0	-															
28	0	-															
29	0	-															
30	0	-															
31	0	-															

Table 15: Bit allocation and possible quantization per sub-band for 24 kHz sampling frequency

Bit rates: 8 kbit/s, 16 kbit/s, 24 kbit/s, 32 kbit/s, 40 kbit/s, 48 kbit/s, 56 kbit/s, 64 kbit/s, 80 kbit/s, 96 kbit/s, 112 kbit/s, 128 kbit/s, 144 kbit/s and 160 kbit/s (all audio modes)																	
index --->																	
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
sb	nbal	nlevels															
0	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383
1	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383
2	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383
3	4	-	3	5	7	9	15	31	63	127	255	511	1 023	2 047	4 095	8 191	16 383
4	3	-	3	5	9	15	31	63	127								
5	3	-	3	5	9	15	31	63	127								
6	3	-	3	5	9	15	31	63	127								
7	3	-	3	5	9	15	31	63	127								
8	3	-	3	5	9	15	31	63	127								
9	3	-	3	5	9	15	31	63	127								
10	3	-	3	5	9	15	31	63	127								
11	2	-	3	5	9												
12	2	-	3	5	9												
13	2	-	3	5	9												
14	2	-	3	5	9												
15	2	-	3	5	9												
16	2	-	3	5	9												
17	2	-	3	5	9												
18	2	-	3	5	9												
19	2	-	3	5	9												
20	2	-	3	5	9												
21	2	-	3	5	9												
22	2	-	3	5	9												
23	2	-	3	5	9												
24	2	-	3	5	9												
25	2	-	3	5	9												
26	2	-	3	5	9												
27	2	-	3	5	9												
28	2	-	3	5	9												
29	2	-	3	5	9												
30	0	-															
31	0	-															

7.1.8 Quantization and coding of sub-band samples

A quantization process of the sub-band samples shall be applied. The following description of this process is informative, but the coding of the sub-band samples has to follow normative rules.

Each of the 12 consecutive sub-band samples, which are grouped together for the scaling process, should be normalized by dividing its value by the Scale Factor to obtain a value denoted X and quantized using the following procedure:

- calculate $A \times X + B$;
- take the n most significant bits;
- invert the MSb.

Table 16: Quantization coefficients

No. of steps	A	B
3	0,750000000	-0,250000000
5	0,625000000	-0,375000000
7	0,875000000	-0,125000000
9	0,562500000	-0,437500000
15	0,937500000	-0,062500000
31	0,968750000	-0,031250000
63	0,984375000	-0,015625000
127	0,992187500	-0,007812500
255	0,996093750	-0,003906250
511	0,998046875	-0,001953125
1 023	0,999023438	-0,000976563
2 047	0,999511719	-0,000488281
4 095	0,999755859	-0,000244141
8 191	0,999877930	-0,000122070
16 383	0,999938965	-0,000061035
32 767	0,999969482	-0,000030518
65 535	0,999984741	-0,000015259

The quantization coefficients **A** and **B** can be found in table 16. The number *n* of bits per codeword, given in table 17, represents the number of bits necessary to encode the number of quantization steps. The inversion of the MSb shall be done in order to avoid the all "1" code that is used for the synchronization word in the MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) header.

Three consecutive sub-band samples, called a granule, shall be considered for coding. Table 17 gives the number of quantization steps that the samples will be quantized to. The same table specifies, whether grouping of a granule shall be used or not. If grouping is not required, the three samples shall be coded with three individual codewords.

If grouping of a granule is required, which depends on the number of quantization steps *m* (*m* = 3, 5 or 9), the three consecutive sub-band samples shall be coded with one codeword. Only one value v_m , Most Significant Byte (MSB) first, shall be transmitted for this grouped granule. The relationship between the coded value v_m and the three samples *x*, *y*, *z* of a granule shall be one of the following:

- $v_3 = 9z + 3y + x$ (v_3 in 0... 26)
- $v_5 = 25z + 5y + x$ (v_5 in 0...124)
- $v_9 = 81z + 9y + x$ (v_9 in 0...728)

Table 17: Classes of quantization

No. of steps	Grouping	Samples per codeword	n bits per codeword
3	yes	3	5
5	yes	3	7
7	no	1	3
9	yes	3	10
15	no	1	4
31	no	1	5
63	no	1	6
127	no	1	7
255	no	1	8
511	no	1	9
1 023	no	1	10
2 047	no	1	11
4 095	no	1	12
8 191	no	1	13
16 383	no	1	14
32 767	no	1	15
65 535	no	1	16

7.1.9 Formatting of the audio bit stream

The frame formatter of the audio encoder shall take the bit allocation, ScFSI, ScF and the quantized sub-band samples together with header information and a few code words used for error detection to format the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) bit stream. It shall further divide this bit stream into audio frames, each corresponding to 1152 PCM audio samples, which is equivalent to a duration of 24 ms in the case of 48 kHz sampling frequency and 48 ms in the case of 24 kHz sampling frequency. The principal structure of such an MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame with its correspondence to the DAB audio frame can be seen in figure 33.

Each audio frame starts with a header, consisting of a syncword and audio system related information. A Cyclic Redundancy Check (CRC), following the header protects a part of the header information, the bit allocation, and the ScFSI fields. After the CRC follows bit allocation, ScFSI and Scale Factors. The sub-band samples, which will be used by the decoder to reconstruct the PCM audio signal, are the last audio data part in the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame before the ancillary data field. This ancillary data field, which is of variable length, is located at the end of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame. The details of the content of the audio frame can be found in clause 7.3.

An adaptation of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame to the DAB audio frame is performed in order to introduce:

- specific DAB Scale Factor Error Check (ScF-CRC);
- a fixed and a variable field of Programme Associated Data (F-PAD and X-PAD).

The lower part of figure 33 indicates how this additional specific information, necessary for DAB, shall be inserted into the ancillary data field of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame.

For MPEG-1 Audio (ISO/IEC 11172-3 [3]) the whole DAB audio frame fits exactly into a DAB logical frame. However, for LSF-coding which is standardized in MPEG-2 Audio (ISO/IEC 13818-3 [11]), the DAB LSF audio frame shall be divided into two subframes of equal length and each subframe fits into two consecutive DAB logical frames.

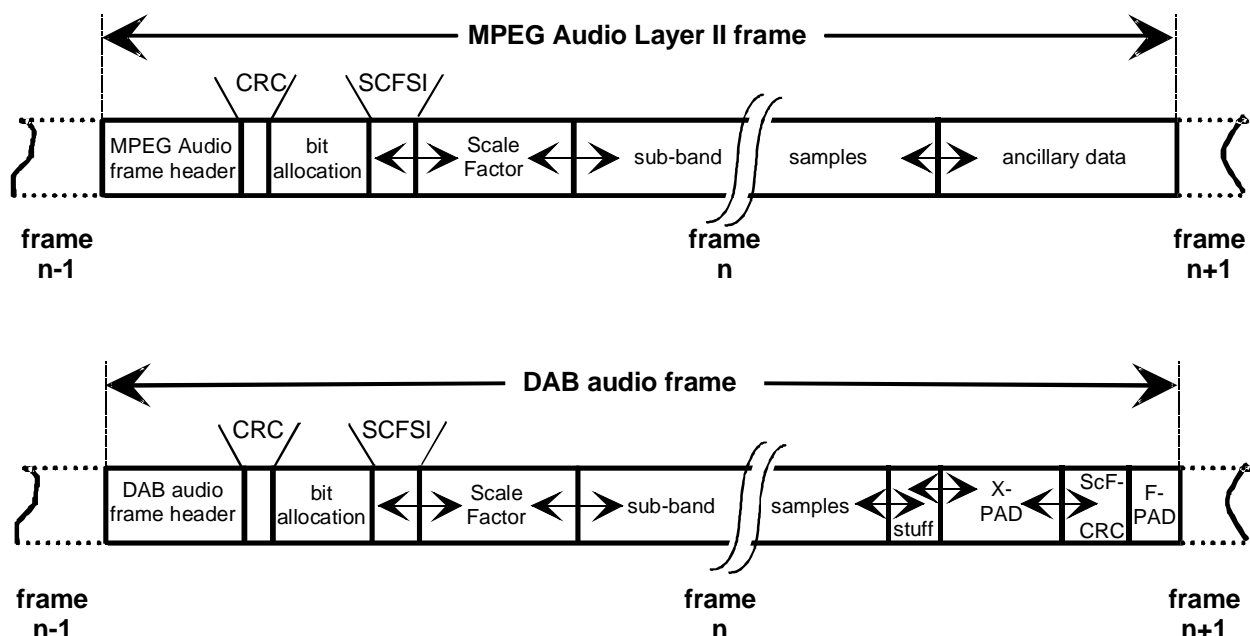


Figure 33: Frame structure of MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) and corresponding DAB audio frame

The first four bytes of the DAB audio frame contain the MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) header. This header carries information for the audio decoder. In the DAB system, some of this information is currently defined as static information. This is:

- **syncword:** set to external synchronization of the audio decoder;
- **layer:** set to Layer II (layer = Layer II);

- **protection_bit:** set to CRC protection on.

7.2 Semantics of the audio bit stream

The following clauses describe the specific semantic meaning of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) bit stream (clause 7.2.1) and its correspondence to the DAB audio bit stream (clause 7.2.2).

7.2.1 MPEG Audio Layer II bit stream

7.2.1.1 Audio sequence

The DAB audio coding system uses the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) format. A graphic representation of an audio frame in MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) format is given in the upper part of figure 33.

Audio_frame: part of the bit stream that is decodable by itself. It contains information for 1 152 samples. It starts with a syncword, and ends just before the next syncword. It consists of an integer number of slots. A slot contains one byte.

7.2.1.2 Audio frame

header: part of the bit stream containing synchronization and state information.

error_check: part of the bit stream containing information for error detection of significant audio side information.

audio_data: part of the bit stream containing information on the audio samples.

ancillary_data: part of the bit stream that may be used for ancillary data.

7.2.1.3 Audio frame header

The first 32 bit (four bytes) are header information.

syncword: the bit string "1111 1111 1111".

ID (Identifier): this 1-bit flag shall identify the audio coding algorithm, as follows:

- 0: ISO/IEC 13818-3 [11] or MPEG-2 Audio extension to lower sampling frequencies;
- 1: ISO/IEC 11172-3 [3].

Layer: this 2-bit field shall indicate which layer is used, according to table 18.

Table 18: Indication of MPEG Audio Layer

Code	Layer
"11"	not used in DAB
"10"	Layer II
"01"	not used in DAB
"00"	reserved

protection_bit: this 1-bit flag shall indicate whether redundancy has been added into the audio bit stream in order to facilitate error detection and concealment. The bit shall be set to "0" because redundancy is added for DAB application.

bit_rate_index: indicates the bit rate. The bit_rate_index is an index to a specified bit rate, shown in table 19 for 48 kHz sampling frequency and shown in table 20 for 24 kHz sampling frequency.

Table 19: Specified total bit rates per audio programme for 48 kHz sampling frequency

bit_rate_index	bit rate specified
"0000"	not used in DAB
"0001"	32 kbit/s
"0010"	48 kbit/s
"0011"	56 kbit/s
"0100"	64 kbit/s
"0101"	80 kbit/s
"0110"	96 kbit/s
"0111"	112 kbit/s
"1000"	128 kbit/s
"1001"	160 kbit/s
"1010"	192 kbit/s
"1011"	224 kbit/s
"1100"	256 kbit/s
"1101"	320 kbit/s
"1110"	384 kbit/s
"1111"	forbidden

Table 20: Specified total bit rates per audio programme for 24 kHz sampling frequency

bit_rate_index	bit rate specified
"0000"	not used in DAB
"0001"	8 kbit/s
"0010"	16 kbit/s
"0011"	24 kbit/s
"0100"	32 kbit/s
"0101"	40 kbit/s
"0110"	48 kbit/s
"0111"	56 kbit/s
"1000"	64 kbit/s
"1001"	80 kbit/s
"1010"	96 kbit/s
"1011"	112 kbit/s
"1100"	128 kbit/s
"1101"	144 kbit/s
"1110"	160 kbit/s
"1111"	forbidden

The bit_rate_index indicates the total bit rate irrespective of the mode (stereo, joint_stereo, dual_channel, single_channel). The total bit rate includes all bits in an audio frame, i.e. all bits necessary for header, audio signal, PAD and error detection information.

NOTE: In order to provide the smallest possible delay and complexity, the decoder is not required to support a continuously variable bit rate. However, the bit rate may change from time to time during continuing service. The smallest resolution for changing the bit rate is 6 seconds (see clause 6.5 on Multiplex re-configuration).

The encoder in the DAB transmitter should support at least one of the bit rates given in tables 20 and 21, whereas the audio decoder shall be capable of working at all these bit rates. For 48 kHz sampling frequency, not all combinations of total bit rates and audio modes are allowed. Table 21 shows the audio modes which can be chosen, dependent on the bit rate.

Table 21: Combinations of total bit rates per audio programme and audio modes for 48 kHz sampling frequency

Total bit rate	Audio modes
32 kbit/s	single_channel
48 kbit/s	single_channel
56 kbit/s	single_channel
64 kbit/s	all modes
80 kbit/s	single_channel
96 kbit/s	all modes
112 kbit/s	all modes
128 kbit/s	all modes
160 kbit/s	all modes
192 kbit/s	all modes
224 kbit/s	stereo, intensity_stereo, dual_channel
256 kbit/s	stereo, intensity_stereo, dual_channel
320 kbit/s	stereo, intensity_stereo, dual_channel
384 kbit/s	stereo, intensity_stereo, dual_channel

sampling_frequency: indicates, depending on the value of the ID, the sampling frequency, according to table 22. The DAB system uses the value of "01", indicating for the ID bit equals "1" a sampling frequency of 48 kHz and for the ID bit equals "0" a sampling frequency of 24 kHz.

Table 22: Specified sampling frequencies per PCM audio input/output signal

sampling_frequency	ID = "0" frequency specified	ID = "1" frequency specified
"00"	not used in DAB	not used in DAB
"01"	24 kHz	48 kHz
"10"	not used in DAB	not used in DAB
"11"	reserved for future use	reserved for future use

padding_bit: fixed value of "0". No padding is necessary for 24 kHz and 48 kHz sampling frequency.

private_bit: bit for private use. This bit will not be used in the future by MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]), and is not interpreted by an MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) decoder.

mode: indicates the audio mode according to table 23. In Layer II the joint_stereo mode is intensity_stereo.

Table 23: Audio modes which can be selected in the audio encoder

mode	Audio mode specified
"00"	stereo
"01"	joint_stereo (intensity_stereo)
"10"	dual_channel
"11"	single_channel

In all audio modes, except joint_stereo, the value of bound equals sblimit. In joint_stereo mode the bound is determined by the mode_extension.

mode_extension: these bits are used in joint_stereo mode, and indicate which sub-bands are in intensity_stereo. All other sub-bands are coded in stereo mode. The figures are given by table 24.

Table 24: Sub-bands in intensity stereo mode, indicated by the mode_extension

mode_extension	Sub-bands in intensity_stereo	Bound
"00"	4 to 31	bound == 4
"01"	8 to 31	bound == 8
"10"	12 to 31	bound == 12
"11"	16 to 31	bound == 16

copyright: if this bit equals "0" there is no copyright on the MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) audio bit stream; "1" means copyright protected.

original/copy: this bit equals "0" if the bit stream is a copy, "1" if it is an original.

emphasis: indicates the type of de-emphasis that shall be used by an MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) decoder. The DAB system shall use a fixed value of "00", indicating "no emphasis", and therefore the use of pre/de-emphasis is excluded (see table 25).

Table 25: Emphasis of the input PCM audio signal

emphasis	emphasis specified
"00"	no emphasis
"01"	not used in DAB
"10"	not used in DAB
"11"	not used in DAB

7.2.1.4 Error check

erc_check: a 16 bit parity check word used for error detection of the most error-sensitive part of the audio information within the encoded audio bit stream. This information includes the third and fourth bytes of the MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) header, bit allocation and Scale Factor Select Information (see for more details clause B.2).

7.2.1.5 Audio data

allocation[ch][sb]: contains information concerning the quantizers used for the samples in sub-band sb in channel ch, whether the information on three consecutive samples of a granule has been grouped to one code, and on the number of bits used to code the samples. The meaning and length of this field depends on the number of the sub-band, the bit rate, and the sampling frequency. The bits in this field form an unsigned integer used as an index to the relevant bit allocation tables 14 to 16, which gives the number of levels "nlevels" used for quantization. For sub-bands in intensity_stereo mode the bit-stream contains only one allocation data element per sub-band.

Table 26: Transmission of Scale Factors dependent on ScFSI

scfsi [ch][sb]	action
"00"	three ScFs transmitted, for parts 0, 1, 2 respectively
"01"	two ScFs transmitted, first one valid for parts 0 and 1, second one for part 2
"10"	one ScF transmitted, valid for all three parts
"11"	two ScFs transmitted, first one valid for part 0, the second one for parts 1 and 2

scfsi[ch][sb]: Scale Factor Selection Information. This gives information on the number of Scale Factors transferred for sub-band sb in channel ch and for which parts of the signal in this frame they are valid (see table 26). The frame is divided into three equal parts of 12 sub-band samples each per sub-band.

scalefactor[ch][sb][p]: indicates the factor by which the re-quantized samples of sub-band sb in channel ch and of part p of the frame should be multiplied. The six bits constitute an unsigned integer, index to table 10, showing the Scale Factors.

grouping[ch][sb]: is a function that determines, whether grouping is applied for coding of samples in sub-band sb of channel ch. Grouping means, that three consecutive samples of the current sub-band sb in channel ch which form the granule gr are coded and transmitted using one common codeword and not using three separate codewords. Grouping[ch][sb] is true, if in the bit allocation table currently in use (see either tables 14 to 16) the value found under sb (first row) and allocation[ch][sb] (column) is either 3, 5 or 9. Otherwise it is false. For sub-bands in intensity stereo mode the grouping is valid for both channels.

samplecode[ch][sb][gr]: coded representation of the three consecutive samples in the granule gr in sub-band sb of channel ch. For sub-bands in intensity stereo mode the coded representation of the samplecode is valid for both channels.

sample[ch][sb][s]: coded representation of the s-th sample in sub-band sb of channel ch. For sub-bands in intensity stereo mode the coded representation of the sample is valid for both channels.

7.2.1.6 Ancillary data

ancillary_bit: user definable.

The number of ancillary bits (`no_of_ancillary_bits`) equals the available number of bits in an audio frame minus the number of bits actually used for header, error check and audio data. The `no_of_ancillary_bits` corresponds to the distance between the end of the audio data in an MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) frame, and the beginning of the header of the next audio frame.

7.2.2 DAB audio bit stream

The DAB system uses the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) format with additional specific information, necessary for the DAB application.

The field for this additional specific information is defined in DAB to contain the DAB fields Extended Programme Associated Data (X-PAD), Audio Scale Factor Error Check (ScF-CRC) and Fixed Programme Associated Data (F-PAD) (see clauses 7.2.2.7 to 7.2.2.9).

7.2.2.1 DAB audio sequence

A detailed graphic representation of the content and the structure of a DAB audio frame is given in figures 34 and 35.

DAB_audio_frame: part of the bit stream that is decodable by itself. Besides the information for 1 152 audio samples, it contains all specific DAB audio information (see also definition given in clause 7.2.1.1).

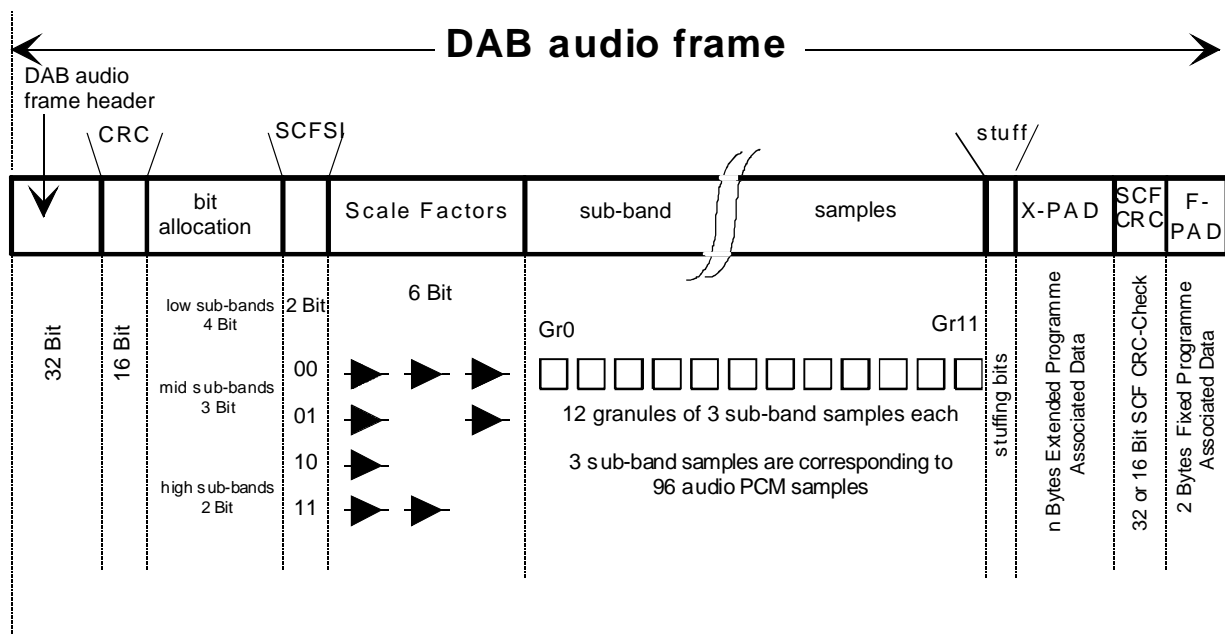


Figure 34: Structure of the DAB audio frame

7.2.2.2 DAB audio frame

DAB_audio_frame_header: part of the bit stream (the first 32 bits) containing relevant state information for the DAB audio decoder.

error_check: see definition given in clause 7.2.1.2.

audio_data: see definition given in clause 7.2.1.2.

audio_stuffing_bits: number of stuffing bits inserted between the end of audio_data and the beginning of x_prog_ass_data.

x_prog_ass_data: part of the DAB audio frame with variable length in multiples of bytes, that may be used for Programme Associated Data.

scf_error_check: part of the DAB audio frame containing information for error detection of ScFs.

f_prog_ass_data: part of the frame with constant length of two bytes, that may be used for Programme Associated Data.

7.2.2.3 DAB audio frame header

The DAB audio frame header is identical to the MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) header.

See definitions given in clause 7.2.1.3 for the semantic meaning of the following parameters:

- bitrate_index;
- sampling_frequency;
- padding_bit;
- private_bit;
- mode;
- mode_extension;
- copyright;
- original/copy;
- emphasis.

7.2.2.4 Error check

See definitions given in clause 7.2.1.4.

7.2.2.5 Audio data

See definitions given in clause 7.2.1.5.

7.2.2.6 Audio stuffing bits

The total number of bits available for audio_data per DAB audio frame for a sampling frequency of 48 kHz equals $(\text{bit_rate} \times 0,024)$ minus bits used by DAB_audio_frame_header(), error_check(), x_prog_ass_data(), scf_error_check(), and f_prog_ass_data(), and in the case of 24 kHz sampling frequency, this number equals $(\text{bit_rate} \times 0,048)$ minus bits used by DAB_audio_frame_header(), error_check(), x_prog_ass_data(), scf_error_check(), and f_prog_ass_data(). The number of bits actually used by audio_data may be less. In this case a number of stuffing bits are inserted between the end of audio_data and the beginning of x_prog_ass_data().

stuff_bit: single bit without useful information. This bit is not defined in DAB. Stuffing bits fill the space from the start of the MPEG Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) ancillary data field up to the beginning of the X-PAD field.

7.2.2.7 Extended Programme Associated Data (X-PAD)

x-pad_byte[i]: i^{th} byte of X-PAD. A variable number of bytes, no_of_x-pad_bytes is used for X-PAD, i.e. the length of this field is variable in multiples of bytes. The actual value is given in clause 7.4.

7.2.2.8 Scale Factor Error Check (ScF-CRC)

scf-crc_check[i]: i^{th} word used for Cyclic Redundancy Check (CRC) words, each protecting the Scale Factors of a group of sub-bands of the following DAB audio frame. The actual number of CRC words, `no_of_scf_error_checks` depends upon the bit-rate and audio mode (see clause B.3). In the case of ISO/IEC 11172-3 [3], either two or four 8-bit cyclic redundancy check words are used for error detection of two or four different spectral groups of Scale Factors within the encoded bit stream. In the case of ISO/IEC 13818-3 [11] always four 8-bit cyclic redundancy check words are used for error detection of four different spectral groups of Scale Factors within the encoded audio bit stream.

7.2.2.9 Fixed Programme Associated Data (F-PAD)

f-pad_byte[i]: i^{th} byte of F-PAD. A fixed number of two bytes for Fixed Programme Associated Data (F-PAD), comprising the last two bytes of the DAB audio frame, is used.

Frame structure of coded bit stream: valid for 1152 PCM audio input samples (stereo mode)

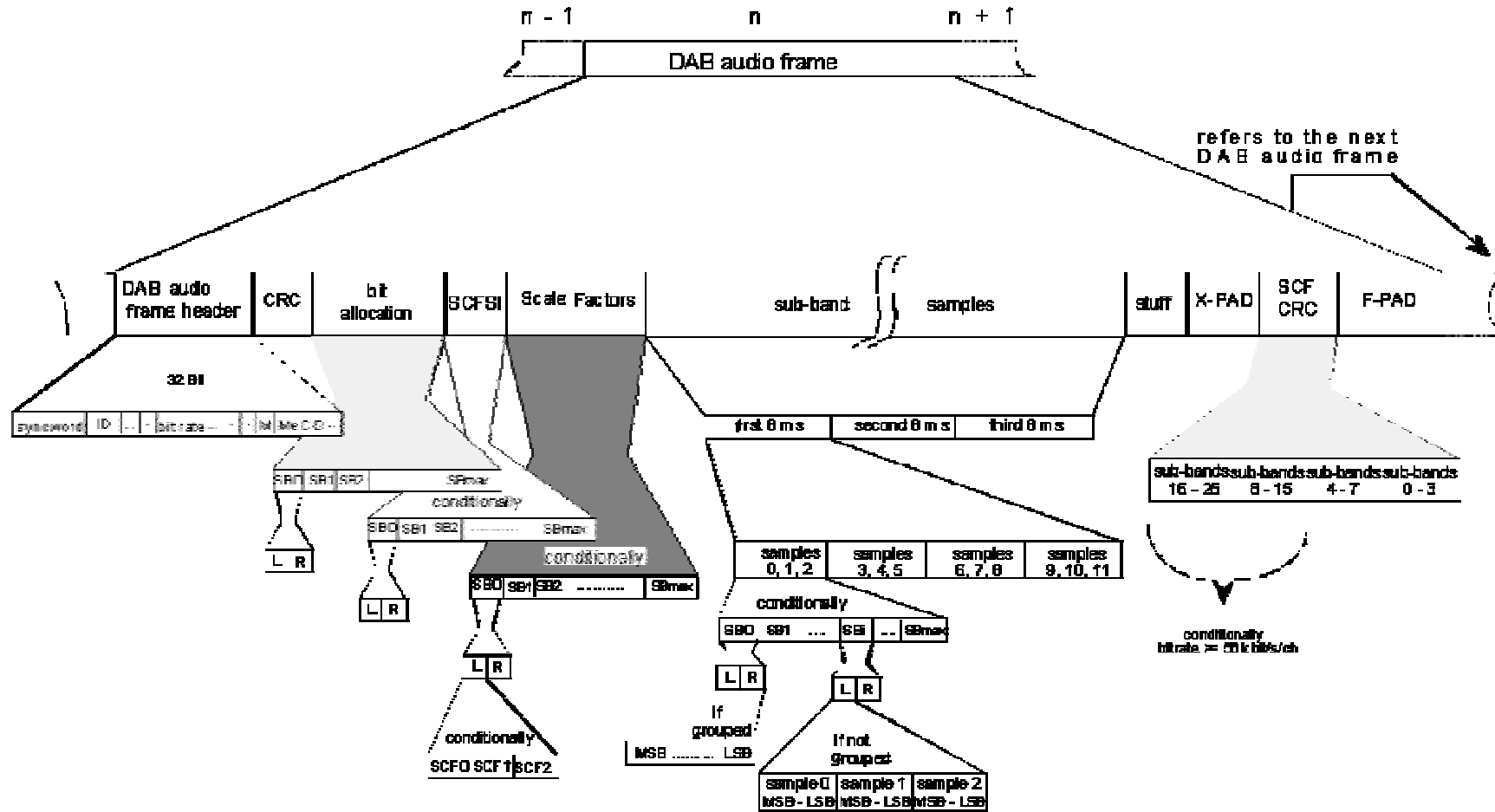


Figure 35: DAB audio frame structure

7.3 Audio bit stream syntax

The details of the audio frame can be found in this clause, which describes the MPEG Audio Layer II bit stream syntax (clause 7.3.1), and the DAB audio bit stream syntax (clause 7.3.2). Apart from the audio stuffing bits, there is no difference in the ISO/IEC 11172-3 [3] Layer II bit stream syntax for 48 kHz sampling frequency and the ISO/IEC 13818-3 [11] Layer II bit stream syntax for 24 kHz sampling frequency. A detailed structure of the DAB audio frame is given in figure 35.

7.3.1 ISO/IEC 11172-3 and ISO/IEC 13818-3 Layer II bit stream syntax

This syntax is valid at the output of an MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) Layer II audio encoder and at the input of an MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) Layer II decoder.

7.3.1.1 Audio sequence

Syntax	No. of bits	Mnemonic
<pre>audio sequence() { while (nextbits()==syncword) { frame() } }</pre>		

7.3.1.2 Audio frame

Syntax	No. of bits	Mnemonic
<pre>frame() { header() error_check() audio_data() ancillary_data() }</pre>		

7.3.1.3 Header

Syntax	No. of bits	Mnemonic
<pre>header() { syncword ID layer protection_bit bitrate_index sampling_frequency padding_bit private_bit mode mode_extension copyright original/copy emphasis }</pre>	<p>12</p> <p>1</p> <p>2</p> <p>1</p> <p>4</p> <p>2</p> <p>1</p> <p>1</p> <p>2</p> <p>2</p> <p>1</p> <p>1</p> <p>1</p> <p>2</p>	<p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p> <p>bslbf</p>

7.3.1.4 Error check

Syntax	No. of bits	Mnemonic
<pre>error_check() { if (protection_bit==0) crc_check } </pre>	16	rpchof

7.3.1.5 Audio data

Syntax	No. of bits	Mnemonic
<pre>audio_data() { for (sb=0; sb<bound; sb++) for (ch=0; ch<nch; ch++) allocation[ch][sb] for (sb=bound; sb<sblimit; sb++) { allocation[0][sb] allocation[1][sb]=allocation[0][sb] } for (sb=0; sb<sblimit; sb++) for (ch=0; ch<nch; ch++) if (allocation[ch][sb]!=0) scfsi[ch][sb] for (sb=0; sb<sblimit; sb++) for (ch=0; ch<nch; ch++) if (allocation[ch][sb]!=0) { if (scfsi[ch][sb]==0) { scalefactor[ch][sb][0] scalefactor[ch][sb][1] scalefactor[ch][sb][2] } if ((scfsi[ch][sb]==1) || (scfsi[ch][sb]==3)){ scalefactor[ch][sb][0] scalefactor[ch][sb][2] } if (scfsi[ch][sb]==2) scalefactor[ch][sb][0] } for (gr=0; gr<12; gr++) { for (sb=0; sb<bound; sb++) for (ch=0; ch<nch; ch++) if (allocation[ch][sb]!=0) { if (grouping[ch][sb]) samplecode[ch][sb][gr] else for (s=0; s<3; s++) sample[ch][sb][3*gr+s] } for (sb=bound; sb<sblimit; sb++) if (allocation[0][sb]!=0) { if (grouping[0][sb]) samplecode[0][sb][gr] else for (s=0; s<3; s++) sample[0][sb][3*gr+s] } } } </pre>	<p>2...4</p> <p>2...4</p> <p>2</p> <p>6</p> <p>6</p> <p>6</p> <p>6</p> <p>6</p> <p>6</p> <p>5...10</p> <p>3..16</p> <p>5...10</p> <p>3...16</p>	<p>uimbsf</p> <p>uimbsf</p> <p>bslbf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p> <p>uimbsf</p>

7.3.1.6 Ancillary data

Syntax	No. of bits	Mnemonic
<pre>ancillary_data() { if ((layer == 1) || (layer == 2)) for (b=0; b<no_of_ancillary_bits; b++) ancillary_bit }</pre>	1	bslbf

7.3.2 DAB audio bit stream syntax

This syntax is valid at the input of the Conditional Access Scrambler (see figure 1) in the DAB transmitter.

7.3.2.1 DAB audio sequence

Syntax	No. of bits	Mnemonic
<pre>dab_audio_sequence() { while true { dab_audio_frame() } }</pre>		

7.3.2.2 DAB audio frame

Syntax	No. of bits	Mnemonic
<pre>dab_audio_frame() { dab_audio_frame_header() error_check() audio_data() audio_stuffing_bits() x_prog_ass_data() scf_error_check() f_prog_ass_data() }</pre>		

7.3.2.3 DAB audio frame header

The DAB audio frame header is defined identically to the header defined in clause 7.3.1.3.

7.3.2.4 Error check

See clause 7.3.1.4.

7.3.2.5 Audio data

See clause 7.3.1.5.

7.3.2.6 Audio stuffing bits

In the case of 48 kHz sampling frequency, i.e. ISO/IEC 11172-3 [3] Layer II, the following syntax is valid.

Syntax	No. of bits	Mnemonic
<pre>audio_stuffing_bits() { while (bitsum < (bit_rate * 0,024 - no_of_x-pad_bytes * 8 - 2* 8 - no_of_scf_error_checks * 8)) { stuff_bit bitsum++ } }</pre>	1	bslbf

In the case of 24 kHz sampling frequency, i.e. ISO/IEC 13818-3 [11] Layer II, the following syntax is valid.

Syntax	No. of bits	Mnemonic
<pre>audio_stuffing_bits() { while (bitsum < (bit_rate * 0,048 - no_of_x-pad_bytes * 8 - 2* 8 - no_of_scf_error_checks * 8)) { stuff_bit bitsum++ } }</pre>	1	bslbf

7.3.2.7 Extended Programme Associated Data

Syntax	No. of bits	Mnemonic
<pre>x_prog_ass_data() { for (i=0; i<no_of_x-pad_bytes; i++) x-pad_byte(i) }</pre>	8	bslbf

7.3.2.8 Scale factor error check

Syntax	No. of bits	Mnemonic
<pre>scf_error_check() { for (i=no_of_scf_error_checks-1; i≥0; i--) scf-crc_check(i) }</pre>	8	rpchof

7.3.2.9 Fixed Programme Associated Data

Syntax	No. of bits	Mnemonic
<pre>f_prog_ass_data() { for (i=0; i<2; i++) f-pad_byte(i) }</pre>	8	bslbf

7.4 Programme Associated Data (PAD)

Each DAB audio frame contains a number of bytes which may carry Programme Associated Data (PAD). PAD is information which is synchronous to the audio and its contents may be intimately related to the audio. The PAD bytes in successive audio frames constitute the PAD channel. The functions provided by PAD are given in clause A.4.

The PAD bytes are always located at the end of each DAB audio frame. With a sampling frequency of 48 kHz, the whole DAB audio frame fits into the 24 ms frame structure of the CIF, and a new set of PAD bytes is available at the receiver every 24 ms. However in the case of a 24 kHz sampling frequency, the DAB LSF audio frame is divided into two parts of equal length (i.e. an even and odd partial frame) and spread across two CIFs. In this case, a new set of PAD bytes is available only every 48 ms.

In each DAB audio frame there are two bytes called the fixed PAD (F-PAD) field. Thus, the bit rate of the F-PAD field depends on the sampling frequency used for the audio coding. The bit rate for F-PAD is 0,667 kbit/s for 48 kHz sampling frequency. In the case of 24 kHz sampling frequency, this value is divided by a factor of two. The F-PAD field is intended to carry control information with a strong real-time character and data with a very low bit rate. The PAD channel may be extended using an Extended PAD (X-PAD) field to carry the dynamic label and data to User Applications. The length of the X-PAD field is chosen by the service provider.

The use of PAD is optional. If no information is sent in the F-PAD, all bytes in the F-PAD field shall be set to zero. This also implies that no X-PAD field is present.

The PAD carried in the DAB audio frame n shall be associated with the audio carried in the following frame, $n+1$.

If functions in PAD are used in dual channel mode, they shall apply to channel 0 unless otherwise signalled by the function.

Figure 36 shows the location of the F-PAD and X-PAD fields within the DAB audio frame.

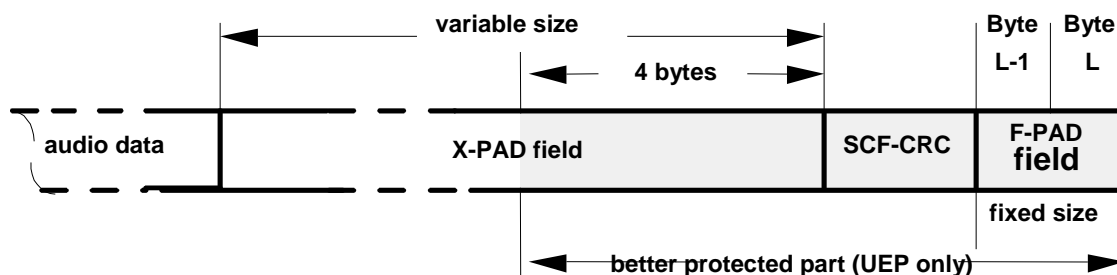


Figure 36: Location of the PAD bytes within the DAB audio frame

The two bytes of the F-PAD field (Byte L-1 and Byte L) are located at the end of the DAB audio frame, following the Scale Factor CRC (ScF-CRC). The X-PAD field is located just before the ScF-CRC. The audio data shall terminate before the beginning of the X-PAD field.

The F-PAD channel carries a two-bit field, "X-PAD Ind", which indicates one of three possibilities for the length of the X-PAD field:

- 1) **No X-PAD:** only the F-PAD field is available. All bits in the frame up to the ScF-CRC may be filled with audio data.
- 2) **Short X-PAD:** in this case the length of the X-PAD field is four bytes in every DAB audio frame, and the entire X-PAD field lies in the better protected part of the DAB audio frame when transmitted with UEP (i.e. is as well protected as the ScF-CRC). In total, 6 bytes carry PAD.
- 3) **Variable size X-PAD:** in this case the length of the X-PAD field may vary from frame to frame. The length of the X-PAD field in the current DAB audio frame can be deduced from the contents information carried within the X-PAD field. When transmitted with UEP, only a part (4 bytes) of the X-PAD field is as well protected as the ScF-CRC. The remainder has a lower protection. Application data carried in the X-PAD channel may require further error protection.

When transmitted with EEP, all bytes have the same level of protection.

7.4.1 Coding of F-PAD

Figure 37 shows the structure of the F-PAD field. The information in Byte L-1 is carried time-multiplexed in one-byte groups that are individually identified by their "F-PAD type". The information carried in Byte L-1 shall be valid for all following audio frames, until it is replaced by new information.

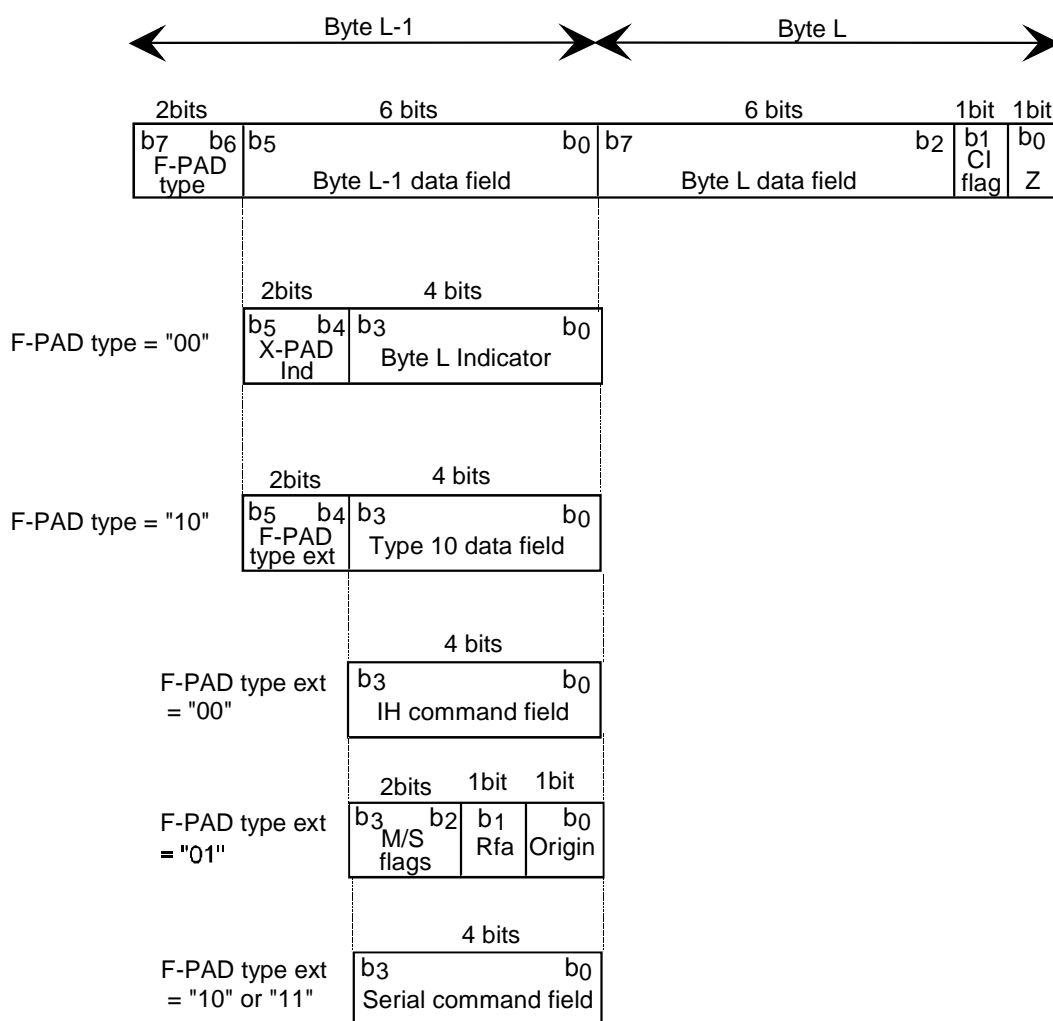


Figure 37: Structure of the F-PAD field

The following definitions apply for Byte L-1:

F-PAD type: this 2-bit field shall indicate the content of the Byte L-1 data field. The values "01" and "11" are reserved for future use of the Byte L-1 data field.

F-PAD type "00":

- **X-PAD Ind (X-PAD Indicator):** this 2-bit field shall indicate the presence and length of the X-PAD field, as follows:

$b_5 - b_4$

- | | |
|------|--------------------------|
| 0 0: | no X-PAD; |
| 0 1: | short X-PAD; |
| 1 0: | variable size X-PAD; |
| 1 1: | reserved for future use. |

- **Byte L Indicator:** this 4-bit field shall indicate the data content of the Byte L data field, as follows:

$b_3 - b_0$

- | | |
|----------|--|
| 0 0 0 0: | In-house information, or no information; |
| 0 0 0 1: | DRC (Dynamic Range Control) data. |

The remaining values are reserved for future use of the Byte L data field.

The coding of the in-house information is not subject to standardization. The coding details of the DRC signal are specified in clause 7.4.1.1.

F-PAD type "10":

- **F-PAD type ext (F-PAD type extension):** this 2-bit field shall indicate the contents of the type 10 data field, as follows:

$b_5 - b_4$

- 0 0: in-house real-time commands;
- 0 1: Music/Speech indication and Origin;
- 1 0: serial command channel (start);
- 1 1: serial command channel (continuation).

- **F-PAD type extension "00":** the in-house real-time commands are not subject to standardization.

- **F-PAD type extension "01":**

- **M/S flags (Music/Speech flags):** this 2-bit flag field shall indicate whether the audio consists of music or speech, or that no music/speech indication is given, as follows:

$b_3 - b_2$

- 0 0: Music/Speech is not signalled;
- 0 1: Music;
- 1 0: speech;
- 1 1: reserved for future use.

- **Rfa:** this 1-bit field shall be reserved for future additions. The bit shall be set to "0" until it is defined.
- **Origin:** this 1-bit field should carry one bit of the ISRC (see ISO 3901 [8]) or EN 797 [12]). The information shall be carried one bit at the time in a packet structure.

A packet shall consist of a sync word, a data identifier and a data field.

The sync word shall consist of the following 9 bits, in the order of transmission: "1111 1111 0".

The data identifier shall comprise 3 bits, as follows (in the order of transmission):

0 0 1: ISRC (ISO 3901 [8]);

0 1 0: UPC/EAN (EN 797 [12]).

All other identifier codes are reserved for future use.

In the case of ISRC, the data field shall consist of 58 bits, representing 5 letter codes (of 6 bits each) followed by 7 digit codes (of 4 bits each).

In the case of UPC/EAN, the data field shall consist of 52 bits, representing 13 digit codes (of 4 bits each).

Each letter or digit code shall be transmitted with MSb first.

If both ISRC and UPC/EAN are transmitted, their packets shall be conveyed alternately. If neither ISRC nor UPC/EAN is transmitted, then the origin bit shall be set to zero.

- **F-PAD type extensions "10" and "11":**
 - **Serial command field:** this 4-bit field is reserved for future use.

The following definitions apply for Byte L:

Byte L data field: the contents of this 6-bit field depend on the Byte L indicator. The coding details for DRC are given in clause 7.4.1.1. The in-house information is not subject to standardization.

CI (Contents Indicator) flag: this 1-bit flag shall signal whether the X-PAD field in the current DAB audio frame includes at least one contents indicator, as follows:

0: no contents indicator;

1: contents indicator(s) present.

Z: this bit shall be set to "0" for synchronization purposes in serial communication links.

7.4.1.1 Dynamic Range Control data

The DRC data is carried in the Byte L data field as described above. The DRC data can be used in the receiver to set the gain of a variable gain amplifier. The DRC data shall be coded as follows:

$b_7 - b_2$ DRC signal;

0 0 0 0 0: 0 dB;

0 0 0 0 1: +0,25 dB;

0 0 0 1 0: +0,50 dB;

↓ - - - - -

- - - - - : continuous steps of +0,25 dB;

- - - - -

1 1 1 1 1: +15,75 dB.

When DRC is used, the DRC data for each DAB audio frame shall be conveyed in the F-PAD of the preceding DAB audio frame. The control information in Byte L-1 is time-multiplexed which allows for an independent operation of DRC data and the Music/Speech flags.

7.4.2 Structure of X-PAD

The X-PAD field contains at least one X-PAD data sub-field, and possibly a number of contents indicators. A contents indicator signals the application type for the data carried in the associated X-PAD data sub-field, and in the case of variable size X-PAD, the length of the sub-field. The user application information in FIG 0/13 indicates the application type(s) used to carry the user application data. The contents indicators may be omitted under certain conditions. Further details on the allowed number of X-PAD data sub-fields and the use of contents indicators are specified in clauses 7.4.2.1, 7.4.2.2 and 7.4.4.

Data carried in the X-PAD field are defined in logical order. Before transmission, the order of the bytes within each X-PAD field shall be reversed. The reversed order applies only to the byte sequence; the bit order within each byte shall not be reversed; MSb shall be transmitted first. This means that the application data is "transmitted before" the contents indicator(s), and that the contents indicator(s) are carried just before the ScF-CRC.

Application data usually requires more than one X-PAD sub-field to be used to transport it. The application data can therefore be structured into X-PAD data groups, which are defined in clause 7.4.5, or sent as a simple byte stream.

Figures 38 and 39 illustrate two examples of how application data, structured into X-PAD data groups, are transported in the X-PAD channel. In the first example the X-PAD data group extends over a number of X-PAD fields (i.e. a number of DAB audio frames), and in the second example three X-PAD data groups are carried in one X-PAD field (i.e. one DAB audio frame). The first example concerns short X-PAD, but similar situations are also possible for variable-sized X-PAD (see clauses 7.4.2.1 and 7.4.2.2). The second example concerns variable-size X-PAD only (see clause 7.4.2.2).

The X-PAD indicator (X-PAD Ind, transported in the F-PAD channel) signals whether no X-PAD, short X-PAD or variable size X-PAD is used. The CI flag signals whether the X-PAD field contains one or more contents indicators (CI) or only application data.

In the first example (figure 38) a single contents indicator is required to indicate the beginning of the X-PAD data group. In the second example (figure 39), three contents indicators are required, one for each data sub-field. In addition, a fourth contents indicator, CI 4, is used to terminate the contents indicator list (see clause 7.4.3).

NOTE: In figures 38 and 39 the logical order of the information is depicted (the transmission order within each DAB audio frame is reversed, as described above).

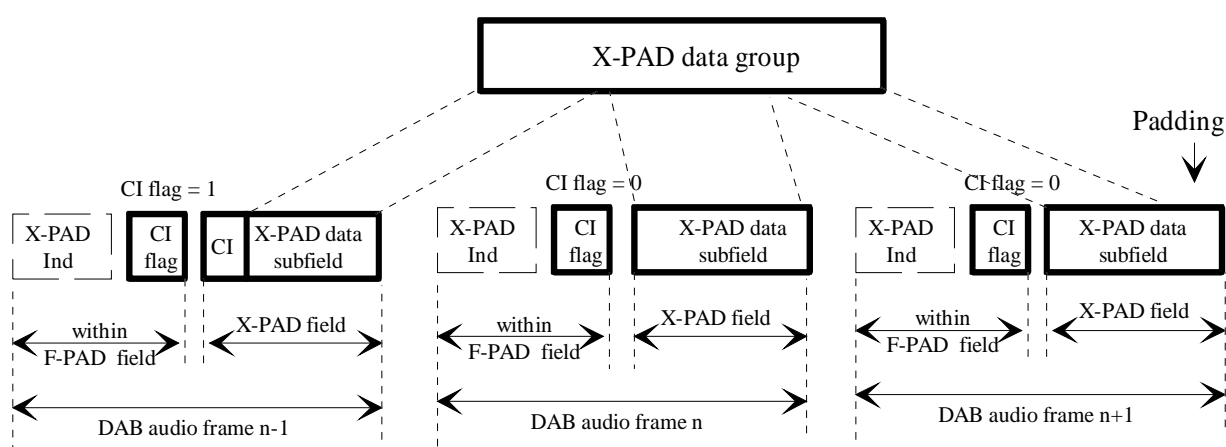


Figure 38: An X-PAD data group extending over three consecutive X-PAD fields

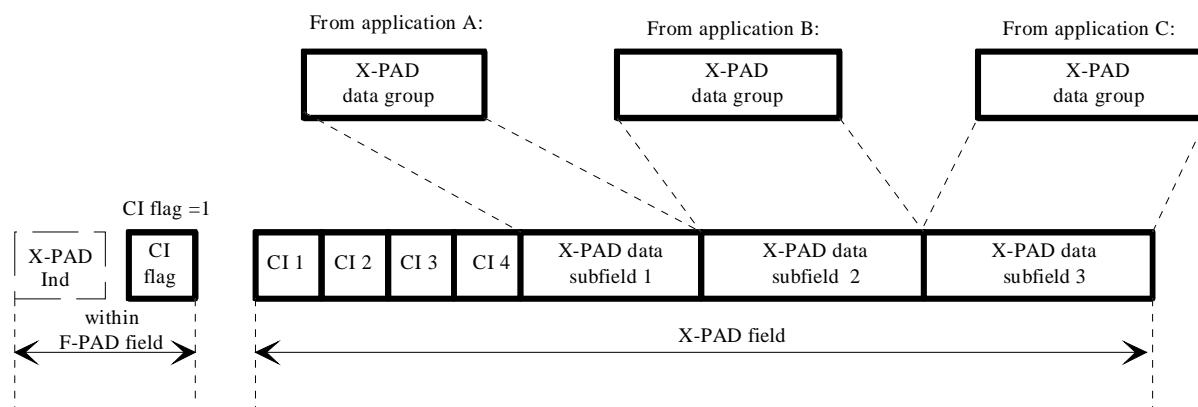


Figure 39: Three X-PAD data groups carried in one X-PAD field

When the X-PAD data group structure is applied, an X-PAD data sub-field may either contain a complete X-PAD data group or a part of a data group. An X-PAD data group may be interrupted by an X-PAD data group for a different user application (or the dynamic label), and resumed later. In this way a time-critical user application can be transported punctually, even if another application requires many X-PAD fields to transport one X-PAD data group.

7.4.2.1 Short X-PAD

The length of the X-PAD field shall be 4 bytes. Each X-PAD field shall comprise either one contents indicator and one X-PAD data sub-field of 3 bytes, or one X-PAD data sub-field of 4 bytes. The contents indicator shall signal the application type.

A contents indicator is required for the following two situations:

- when the X-PAD data sub-field contains the start of an X-PAD data group;
- when the X-PAD data sub-field contains data from an X-PAD data group or byte stream that has been interrupted and now is being resumed.

The contents indicator may be omitted if the X-PAD data sub-field (4 bytes long) contains a continuation of the X-PAD data group or the byte stream carried in the previous DAB audio frame (i.e. data for the same user application).

If the final part of an X-PAD data group does not entirely fill the X-PAD data sub-field in which it is transported, padding bits shall be used to fill the X-PAD sub-field. Padding bits shall be set to zero.

The contents indicator flag, transported in the F-PAD field, shall signal for each DAB audio frame, whether the X-PAD field contains a contents indicator or not.

7.4.2.2 Variable size X-PAD

The length of the X-PAD field may vary from one DAB audio frame to the next.

The contents indicators shall, when present, be assembled in a contents indicator list in the beginning (logical meaning) of the X-PAD field. Each X-PAD field shall comprise either one X-PAD data sub-field or a number of X-PAD data sub-fields, together with a contents indicator list.

Each contents indicator shall signal the application type for the data in the associated X-PAD data sub-field and the length of the sub-field. The total length of the X-PAD field may therefore be derived from the contents indicators.

The maximum number of data sub-fields within one X-PAD field is four. When more than one data sub-field is included there shall be a contents indicator associated with each sub-field. The order of the contents indicators within the list shall be the same as the order of the X-PAD data sub-fields, i.e. the first contents indicator is associated to the first X-PAD data sub-field, the second contents indicator to the second X-PAD data sub-field, etc.

The contents indicators are 1 byte long. The contents indicator list shall comprise up to 4 bytes, thereby allowing up to four X-PAD data sub-fields within one X-PAD field.

If the contents indicator list is shorter than four bytes, an end marker, consisting of a contents indicator of application type 0, shall be used to terminate the list, see clause 7.4.3.

A contents indicator list shall be included whenever any of the following situations apply:

- when there is more than one X-PAD data sub-field in the X-PAD field;
- when an X-PAD data sub-field contains the start of an X-PAD data group;
- at intervals allowing quick synchronization of terminals when an X-PAD data sub-field contains data from a byte stream;
- when an X-PAD data sub-field contains data from an X-PAD data group or a byte stream that has been interrupted and is now being resumed;
- when the capacity of the X-PAD channel is changed;
- when there is only one X-PAD data sub-field which does not fill the X-PAD field.

The contents indicator list may be omitted if both of the following conditions apply:

- the length of the X-PAD field is the same as in the previous DAB audio frame;
- the X-PAD field comprises a single data sub-field containing a continuation of the X-PAD data group or the byte stream carried in the last (logical meaning) X-PAD data sub-field of the previous DAB audio frame (i.e. data for the same user application).

If the final part of an X-PAD data group does not entirely fill the X-PAD data sub-field in which it is transported, padding bits shall be used to fill the X-PAD sub-field. Padding bits shall be set to zero.

The contents indicator flag, transported in the F-PAD field, shall signal for each DAB frame, whether the X-PAD field contains contents indicators or not.

7.4.3 Application types

There are a maximum of 31 application types available.

For applications that may generate long X-PAD data groups, two application types are defined: one is used to indicate the start of an X-PAD data group and the other is used to indicate the continuation of a data group after an interruption. Byte streams require just one X-PAD application type.

Application type 0 shall be used as the end marker. The end marker shall be used for two purposes:

- 1) to terminate the contents indicator list when, for the variable size X-PAD, there is a contents indicator list shorter than four bytes;
- 2) to signal that the X-PAD field contains no data.

Application type 1 shall be used for the data group length indicator (see clause 7.4.5.1).

Application types 2 and 3 shall be used for the dynamic label (see clause 7.4.5.2).

Application types 12 to 15 should be used for an MOT-based user application to provide compatibility with early receiver implementations. They shall not be used for other user applications.

Application type 31 shall not be used.

All other application types (4 to 11 inclusive and 16 to 30 inclusive) shall be used as identifiers for the user application data transported in the X-PAD. The correspondence between the application types used and the user application is signalled by FIG 0/13. Table 27 summarises the use of the application types.

Table 27: X-PAD Application types

Application type	Description
0	End marker
1	Data group length indicator
2	Dynamic label segment, start of X-PAD data group
3	Dynamic label segment, continuation of X-PAD data group
4 to 11	User defined
12	MOT, start of X-PAD data group, see EN 301 234 [14]
13	MOT, continuation of X-PAD data group, see EN 301 234 [14]
14	MOT, start of CA messages, see EN 301 234 [14]
15	MOT, continuation of CA messages, see EN 301 234 [14]
16 to 30	User defined
31	Not used

The user defined application types shall be used as follows:

- If the user application uses a byte stream, then one application type is used by the user application.
- If the user application uses the X-PAD data group structure, then two consecutive application types are used (start and continuation).

- If the user application applies conditional access, then one (CA as byte stream) or two (CA as X-PAD data group structure) additional and consecutive application types are used.

7.4.4 Contents indicator

The format of the contents indicator depends on whether short X-PAD or variable size X-PAD is used, as described in the following clauses.

7.4.4.1 Contents indicator in short X-PAD

The coding of the contents indicator in the case of short X-PAD is shown in figure 40.

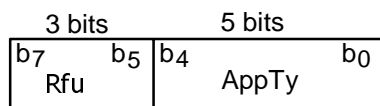


Figure 40: Contents indicator for short X-PAD

The following definitions apply:

Rfu: this 3-bit field is reserved for future use. All bits shall be set to zero until they are defined.

AppTy (Application Type): this 5-bit field shall specify an application type. Application types shall be coded as unsigned binary numbers.

7.4.4.2 Contents indicator in variable size X-PAD

The coding of the contents indicator in the case of variable size X-PAD is shown in figure 41.

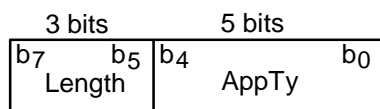


Figure 41: Contents indicator for variable size X-PAD

The following definitions apply:

Length: this 3-bit field shall indicate the length of the associated X-PAD data sub-field (in the current audio frame), as follows:

$b_7 - b_5$

0 0 0: 4 bytes;

0 0 1: 6 bytes;

0 1 0: 8 bytes;

0 1 1: 12 bytes;

1 0 0: 16 bytes;

1 0 1: 24 bytes;

1 1 0: 32 bytes;

1 1 1: 48 bytes.

AppTy (Application Type): this 5-bit field shall specify an application type. Application types shall be coded as unsigned binary numbers.

7.4.5 Applications in X-PAD

This clause contains the coding details for the X-PAD data groups used to carry MSC data groups and the dynamic label segments. A Cyclic Redundancy Check is used for error detection.

The CRC shall be generated according to the procedure defined in annex E. The generation shall be based on the polynomial:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC word shall be complemented (1s complement) prior to transmission. At the beginning of each CRC word calculation, all register stages shall be initialized to "1".

One or more padding bytes which shall be set to zero may be included after the CRC to fill up the X-PAD data sub-field carrying the last part of the X-PAD data group.

7.4.5.1 MSC data groups in X-PAD

User applications may use the X-PAD to transport MSC data groups. In this case two X-PAD data groups are used to carry one MSC data group. The first X-PAD data group is used to signal the length of the following MSC data group, and the second X-PAD data group is used to transport the MSC data group itself.

7.4.5.1.1 X-PAD data group for data group length indicator

The X-PAD data group for data group length indicator signals the length of the following MSC data group and is indicated by application type 1. Figure 42 shows the structure of the X-PAD data group for the data group length indicator.

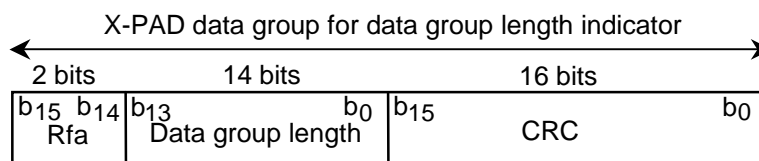


Figure 42: Structure of the X-PAD data group for the data group length indicator

Rfa: This field shall be reserved for future additions. The bits shall be set to "0" until defined.

Data group length: This 14-bit field shall indicate the length of the following X-PAD data group (MSC Data Group) in bytes. It is coded as an unsigned binary number. The Data group length covers the data group header, the session header, the data group data field and the optional CRC, if present. The structure of the MSC data group is shown in figure 9.

CRC (Cyclic Redundancy Check): this CRC shall be calculated on the Rfa and the Data group length field.

7.4.5.1.2 X-PAD data group for MSC data group

The X-PAD data group for MSC data group carries one complete MSC data group. Figure 43 shows the structure of the X-PAD data group for MSC data group.

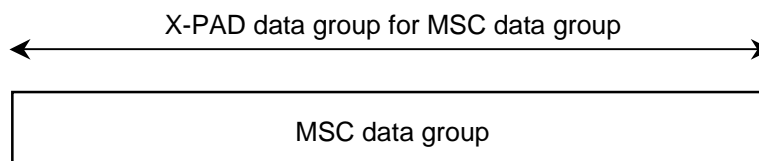


Figure 43: Structure of the X-PAD data group for MSC data group

MSC data group: This field contains a complete MSC data group.

NOTE: It is recommended that the MSC data group includes the MSC data group CRC.

7.4.5.1.3 Transport of MSC data groups in short X-PAD

In the case of short X-PAD, audio frame n shall contain a contents indicator carrying application type 1 and the first three bytes of the X-PAD data group for data group length indicator. Audio frame $n+1$ shall contain the final byte of the X-PAD data group for data group length indicator and three bytes of padding. Audio frame $n+2$ shall contain a contents indicator carrying the appropriate "Start of X-PAD data group" application type and the first three bytes of the X-PAD data group for MSC data group application data. Subsequent audio frames shall continue according to the general rules (i.e. data applications may be interrupted by other data applications and resumed later).

7.4.5.1.4 Transport of MSC data groups in variable-sized X-PAD

In the case of variable-sized X-PAD, contents indicators shall be used to signal application type 1 and then the appropriate "Start of X-PAD data group" application type for two consecutive X-PAD data sub-fields. The X-PAD data sub-field containing the X-PAD data group for data group length indicator and the X-PAD data sub-field containing the start of the following X-PAD data group containing the MSC data group shall not be interrupted by another X-PAD sub-field. This is to ensure the close and unique link between the data group length indicator and the X-PAD data group (MSC data group) it is referring to.

7.4.5.2 Dynamic label

The dynamic label may comprise up to 8 segments, each consisting of up to 16 characters. Each segment is carried in one X-PAD data group. Figure 44 shows the structure of the X-PAD data group for the Dynamic label segment.

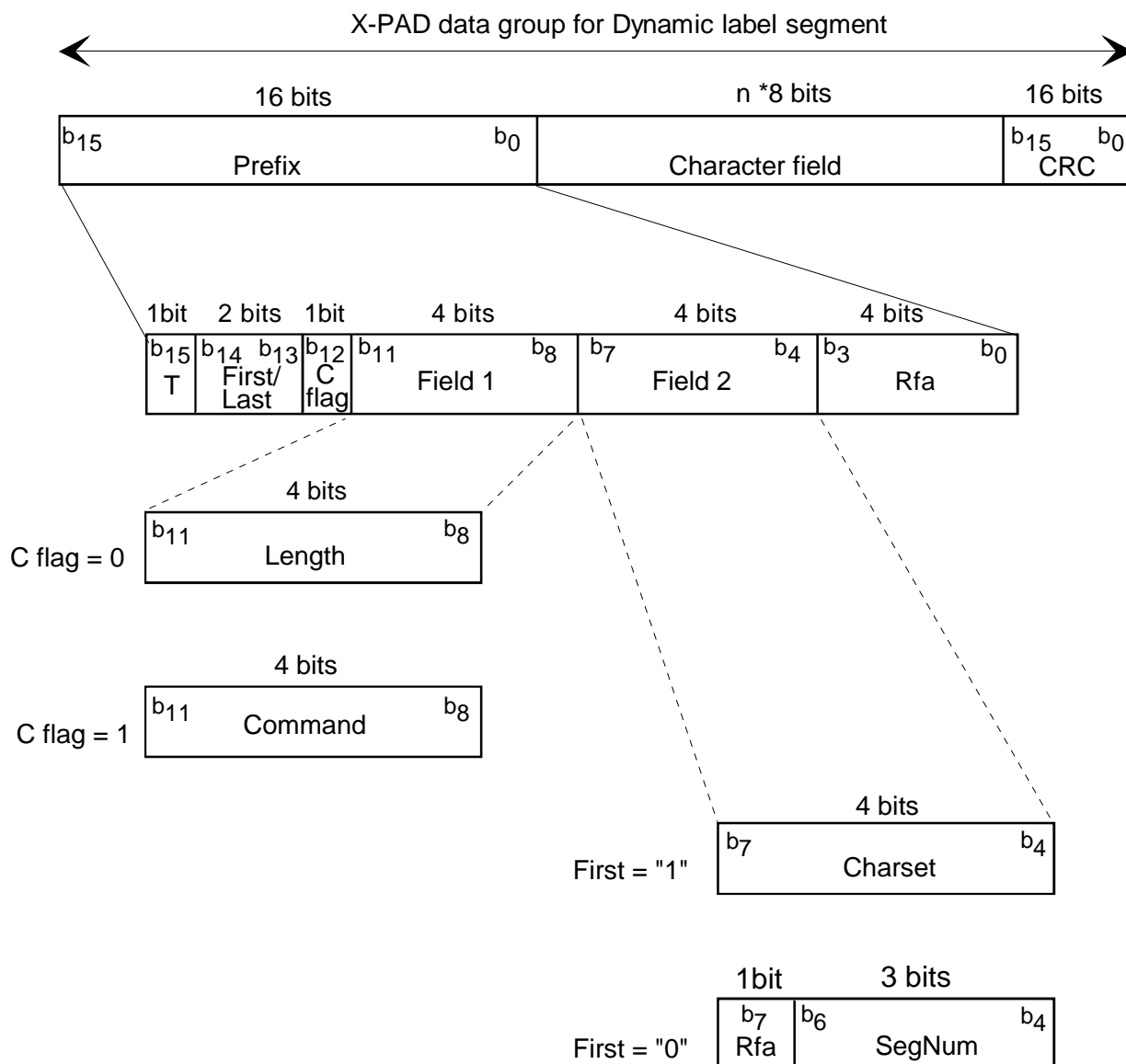


Figure 44: Structure of the X-PAD data group for each dynamic label segment

The following definitions apply:

Prefix:

- **T (Toggle bit):** this bit shall be maintained in the same state as long as segments from the same label are being transmitted. When a segment from a different dynamic label is sent for the first time, this bit shall be inverted with respect to its previous state. If a dynamic label, which may consist of several segments, is repeated, then this bit shall remain unchanged.
- **First/Last:** These flags shall be used to identify particular segments which form a succession of segments in a dynamic label. The flags shall be assigned as follows:

First b_{14}	Last b_{13}	The segment is:
0	0	: an intermediate segment;
0	1	: the last segment;
1	0	: the first segment;
1	1	: the one and only segment.

- **C (Command) flag:** this 1-bit flag shall signal whether Field 1 contains the length of the label segment or a special command, as follows:
 - 0: Field 1 signals the length of the label segment;
 - 1: Field 1 contains a special command.
- **Field 1:**
 - **Length:** this 4-bit field, expressed as an unsigned binary number, shall specify the number of bytes in the character field minus 1.
 - **Command:** this 4-bit field shall contain a special command, as follows (all other codes are reserved for future use):
 - $b_{11} - b_8$
 - 0 0 0 1: the label shall be removed from the display.
- **Field 2:** this 4-bit field shall contain either a character set identifier or a segment number, depending on the value of the First flag (b14).
 - **First flag = "1":**
 - **Charset:** see clause 5.2.2.2.
 - **First flag = "0":**
 - **Rfa:** this 1-bit field is reserved for future additions. The bit shall be set to zero until it is defined.
 - **SegNum (Segment Number):** this 3-bit field, expressed as an unsigned binary number, shall specify the sequence number of the current segment minus 1. (The second segment of a label corresponds to SegNum=1, the third segment to SegNum=2, etc.) The value 0 is reserved for future use.
- **Rfa:** this 4-bit field shall be reserved for future additions. These bits shall be set to zero until they are defined.

Character field: this field shall define the payload of the dynamic label segment. It shall be coded as a string of characters (maximum 16) which are chosen from the character set signalled by Charset field in the prefix. If the last character of a Dynamic label segment is a multibyte character and not all bytes fit into the character field it is permitted to continue the character in the next Dynamic label segment. The first character starts with the first byte of the first dynamic label segment. This field shall be omitted when the C flag = "1" (special command).

The following additional codes may be used with any of the character sets:

- Code 0A (hex) may be inserted to indicate a preferred line break.
- Code 0B (hex) may be inserted to indicate the end of a headline. Headlines shall be restricted to a maximum length of 2×16 displayable characters (including hyphens introduced as a result of a control code 1F) and may contain 0 or 1 preferred line breaks codes (Code 0A). There may not be more than sixteen characters before any line-break and there may not be more than sixteen characters after any line-break.
- Code 1F (hex) may be inserted to indicate a preferred word break. This code may be used to display long words comprehensibly.

CRC (Cyclic Redundancy Check): this CRC shall be calculated on the prefix and the character field.

8 Data features

This clause describes the coding of Service Information (SI) and some general data applications.

8.1 Service Information (SI)

8.1.1 Introduction

SI provides supplementary information about services, both audio programme and data. It does not include Multiplex Configuration Information (MCI) which is treated separately (see clause 6). The following clauses describe the SI features. Service-related features include announcements, the service component trigger and Frequency Information (FI). The language feature allows the language associated with a service component to be signalled. Programme-related features include Programme Number and programme type. The services, Programme Number (PNum), programme type, FI and the announcement features associated with other ensembles are signalled separately. Provision is made to signal the radio frequencies associated with FM and AM services and traffic announcements carried on FM services. Labels are provided for the ensemble and individual services. Also, there are features to give the time and country identifiers and to associate transmitter identification codes with geographical locations.

The coding of these features in the Fast Information Channel (FIC) is given by reference to their FIG type and extension (see clause 5.2). Generally, the SI is encoded in FIG Types 0 and 1: some extensions are reserved for future use.

8.1.2 Service component language

The service component language feature is used to signal a language associated with a service component. The feature is encoded in Extension 5 of FIG type 0 (FIG 0/5). Figure 45 shows the structure of the service component language field which is part of the Type 0 field (see also figure 4).

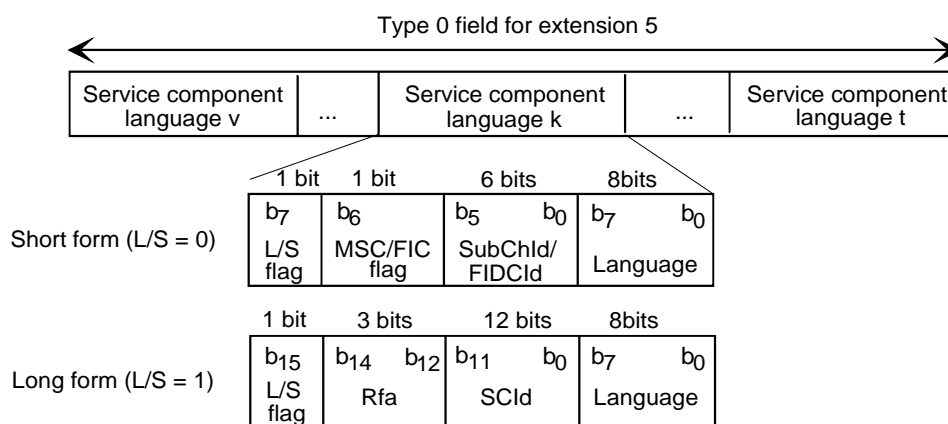


Figure 45: Structure of the service component language field

The following definitions apply:

L/S flag: this 1-bit flag shall indicate whether the service component identifier takes the short or the long form, as follows:

0: short form;

1: long form.

Short form:

- **MSC/FIC flag:** this 1-bit flag shall indicate whether the component is carried in the MSC in Stream mode or in the FIC, and whether the subsequent field contains the SubChId or the FIDCId (see clause 6.3.1), as follows:

0: MSC in Stream mode and SubChId identifies the sub-channel;

1: FIC and FIDCId identifies the component.

- **SubChId (Sub-channel Identifier):** this 6-bit field shall identify the sub-channel in which the service component is carried;
- **FIDCId (Fast Information Data Channel Identifier):** this 6-bit flag shall identify the service component carried in the FIDC (see clause 6.3.1);
- **Language:** this 8-bit field shall indicate the language of the audio or data service component. It shall be coded according to TS 101 756 [16], tables 9 and 10.

Long form:

- **Rfa:** this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined;
- **SCId:** this 12-bit field shall identify the service component (see clause 6.3.1);
- **Language:** see above.

8.1.3 Time and country identifier

8.1.3.1 Date and time (d&t)

The date and time feature is used to signal a location-independent timing reference in UTC format. This feature is encoded in Extension 10 of FIG type 0 (FIG 0/10). Figure 46 shows the structure of the date and time field which is part of the Type 0 field (see also figure 4). The time reference shall be defined by the synchronization channel (see clause 14.3.3).

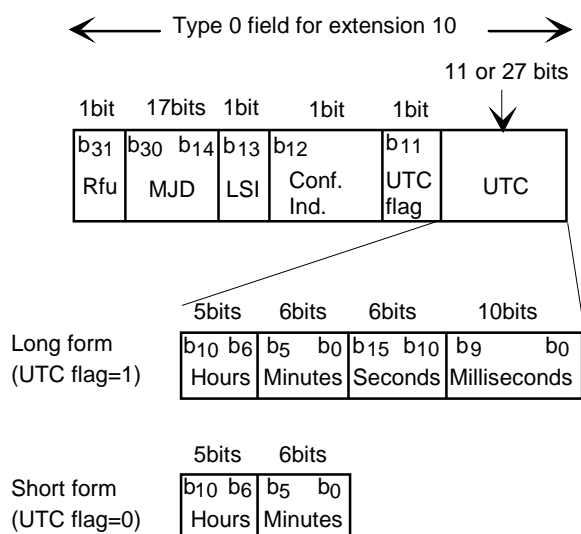


Figure 46: Structure of the date and time field

The following definitions apply:

Rfu: this 1-bit field shall be reserved for future use of the remainder of the Type 0 field for extension 10. The bit shall be set to zero for the currently specified definition of this field.

MJD (Modified Julian Date): this 17-bit binary number shall define the current date according to the Modified Julian coding strategy (see EN 62106 [5]). This number increments daily at 0000 Co-ordinated Universal Time (UTC) and extends over the range 0-99 999. As an example, MJD 50 000 corresponds to 1995 October 10.

LSI (Leap Second Indicator): this 1-bit flag shall be set to "1" throughout a UTC day containing a leap second.

Conf. Ind. (Confidence Indicator): this 1-bit field shall be set to "1" when the timing information is within an agreed tolerance (for example, $\pm 0,2$ ms at first ground fall).

UTC flag: this 1-bit field shall indicate whether the UTC (see below) takes the short form or the long form, as follows:

- 0: UTC short form;
- 1: UTC long form.

UTC (Co-ordinated Universal Time): two forms are available depending upon the state of the UTC flag. They shall be defined as follows:

- **short form:** this 11-bit field contains two sub-fields, coded as unsigned binary numbers. The first sub-field is a 5-bit field which shall define the hours and the other sub-field is a 6-bit field which shall define the minutes;
- **long form:** in addition to the hours and minutes fields defined in the short form, this 27-bit field shall contain two further sub-fields, both of which shall be coded as unsigned binary numbers. The first is a 6-bit field which shall define the seconds and the other is a 10-bit field which shall define the milliseconds.

8.1.3.2 Country, LTO and International table

The Country, LTO and International table feature defines the local time offset, the International Table and the Extended Country Code (ECC). The feature is encoded in Extension 9 of FIG type 0 (FIG 0/9). Figure 47 shows the structure of the country, LTO and international table field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). Changes to the database shall be signalled using the CEI.

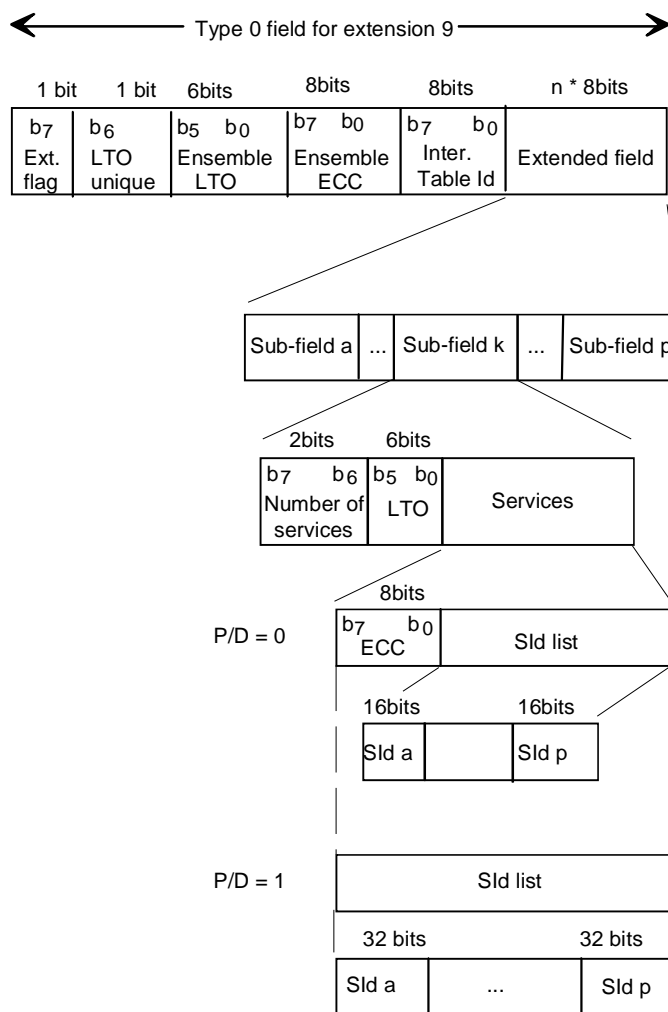


Figure 47: Structure of the country field

The following definitions apply:

Ext. (Extension) flag: this 1-bit flag shall indicate whether the Extended field is present or not, as follows:

0: extended field absent;

1: extended field present.

LTO unique: this 1-bit flag shall indicate whether the ensemble covers one or several time zones, as follows:

0: one time zone (time specified by Ensemble LTO);

1: several time zones.

Ensemble LTO (Local Time Offset): this 6-bit field shall give the Local Time Offset (LTO) for the ensemble. It is expressed in multiples of half hours in the range -12 hours to +12 hours. bit b_5 shall give the sense of the LTO, as follows:

0: positive offset;

1: negative offset.

Ensemble ECC (Extended Country Code): this 8-bit field shall make the Ensemble Id unique worldwide. The ECC shall be as defined in TS 101 756 [16], tables 3 to 7.

Inter. (International) Table Id: this 8-bit field shall be used to select an international table. The interpretation of this field shall be as defined in TS 101 756 [16], table 11.

Extended field: this $n \times 8$ -bit field shall contain one or more sub-fields, which define those services for which either their associated LTO or ECC, or both, differ from that of the ensemble. The maximum length of the extended field is 25 bytes. The following definitions apply to each sub-field:

- **Number of services:** this 2-bit field, expressed as an unsigned binary number, shall indicate the number of services (in the range 0 to 3) contained in the subsequent SId list;
- **LTO (Local Time Offset):** this 6-bit field shall be coded in the same way as the Ensemble LTO;
- **ECC (Extended Country Code):** this 8-bit field shall be coded in the same way as the Ensemble ECC;
- **SId (Service Identification):** this 16 or 32-bit field shall identify the service, see clause 6.3.1.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) only.

The Change Event Indication (CEI) is signalled by the **Ext. flag** = 1, the **Number of services** field = 0, and the **LTO** field = 0.

8.1.4 Programme Number

The Programme Number (PNum) feature is used to signal a machine-readable programme identifier. The feature is encoded in Extension 16 of FIG type 0 (FIG 0/16). Figure 48 shows the structure of the Programme Number field which is part of the Type 0 field (see also figure 4).

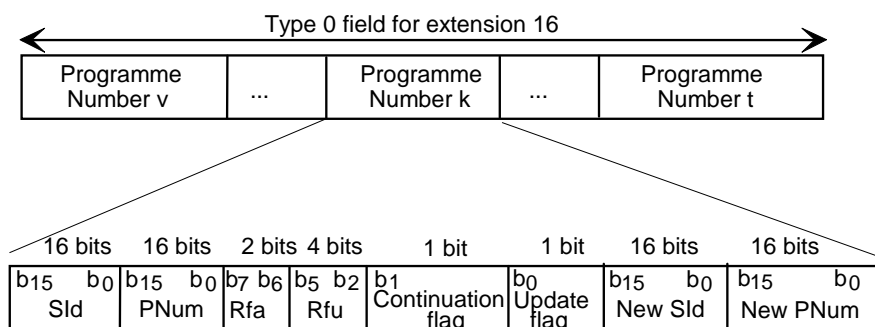


Figure 48: Structure of Programme Number field

The following definitions apply:

SIId (Service Identifier): this 16-bit field shall identify the service (see clause 6.3.1).

PNum (Programme Number): this 16-bit field shall define the date and time at which a programme begins. This field is coded in the same way as the RDS "Programme Item Number (PIN)" feature (EN 62106 [5]).

Rfa: this 2-bit field shall be reserved for future additions. The bits shall be set to "0" until they are defined.

Rfu: this 4-bit field shall be reserved for future use of the associated New SIId and New PNum fields. The Rfu bits shall be set to zero for the currently specified definition of these fields.

Continuation flag: this 1-bit flag shall indicate that there will be a planned interruption to the programme, but the programme will be continued later. It is coded as follows:

0: the programme will not be subject to a planned interruption;

1: the programme will be interrupted but continued later.

Update flag: this 1-bit flag shall indicate a re-direction to a different service and time, as follows:

0: no re-direction;

1: re-direction.

In the case of a re-direction, the New SIId and New PNum shall be appended:

New SIId: this 16-bit field shall contain the SIId of the target service of the re-direction.

New PNum: this 16-bit field shall specify a new time of emission or a time at which the programme will be continued. It shall be coded in the same way as PNum.

NOTE: Special codes are allowed when the date part of the PNum field signals date = "0". In this case, the hours and minutes part of the field shall contain a special code, as follows:

Date	Hours	Minutes	Code description
0	0	0	Status code: no meaningful PNum is currently provided.
0	0	1	Blank code: the current programme is not worth recording.
0	0	2	Interrupt code: the interrupt is unplanned (for example a traffic announcement).

8.1.5 Programme Type

The Programme Type (PTy) feature allows programme contents to be categorized according to their intended audience.

The Programme Type feature is encoded in Extension 17 of FIG type 0 (FIG 0/17). It consists of at least one code from the international set of codes followed by an optional additional code. The Programme Type codes apply to all the audio components of the service. The language field allows the language of the primary service component to be signalled. In addition, one language can be signalled for the secondary service component(s). Figure 49 shows the structure of Programme Type field which is part of the Type 0 field (see also figure 4).

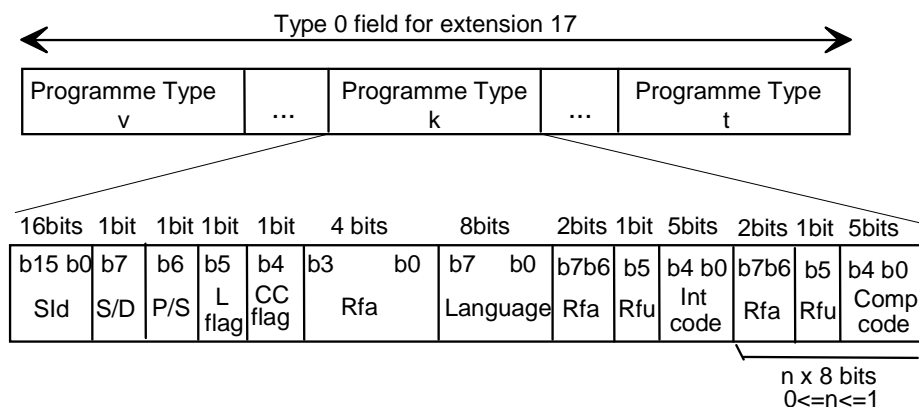


Figure 49: Structure of the Programme Type field

The following definitions apply:

SId (Service Identifier): this 16-bit field shall identify the service (see clause 6.3.1).

S/D (Static/Dynamic): this 1-bit flag shall indicate that the Programme Type codes, and language (when present), signalled in the programme type field, represent the current programme contents, as follows:

0: Programme Type codes and language (when present), may not represent the current programme contents;

1: Programme Type codes and language (when present), represent the current programme contents.

P/S (Primary/Secondary): this 1-bit flag shall indicate whether the language refers to a primary or a secondary service component, as follows:

0: primary service component;

1: secondary service component.

If no language is signalled (language field absent, L flag = 0), then the P/S flag is meaningless and shall be set to "0".

L (Language) flag: this 1-bit flag shall indicate whether or not the language field is present, as follows:

0: language field absent;

1: language field present.

CC (Complementary Code) flag: this 1-bit flag shall indicate whether or not the complementary code field and the preceding Rfa and Rfu fields are present, as follows:

0: complementary code and preceding Rfa and Rfu fields absent;

1: complementary code and preceding Rfa and Rfu fields present.

Rfa: this 4-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

Language: this 8-bit field shall indicate the language of the audio. It shall be coded according to TS 101 756 [16], tables 9 and 10.

Rfa: this 2-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

Rfu: this 1-bit field shall be reserved for extending the international code field range. The bit shall be set to "0" for the currently specified international code field.

Int. (International) code: this 5-bit field shall specify the basic Programme Type (PTy) category. This code is chosen from an international table (see clause 8.1.3.2).

Rfa: this 2-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

Rfu: this 1-bit field shall be reserved for extending the complementary code field range. The bit shall be set to "0" for the currently specified complementary code field.

Comp. (Complementary) code: this 5-bit field shall specify the complementary PTy category which should be chosen from an international table (see clause 8.1.3.2).

8.1.6 Announcements

The announcement feature is effected in two stages. The announcement support assigns, to a service, the types of announcements by which the service may be interrupted and the links to other services which share the same interruption privileges. This support information is relatively static. The announcement switching provides the dynamic signal to allow a vectored interruption of the reception of the service by another carrying an announcement.

8.1.6.1 Announcement support

The announcement support feature is encoded in Extension 18 of FIG type 0 (FIG 0/18). Figure 50 shows the structure of announcement support field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

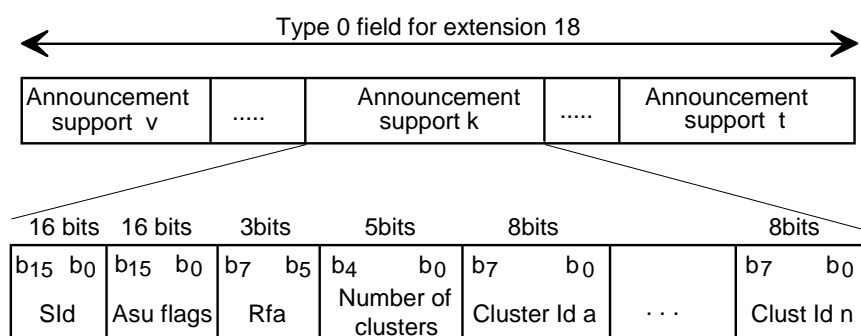


Figure 50: Structure of announcement support field

The following definitions apply:

SId (Service Identifier): this 16-bit field shall identify the service (see clause 6.3.1).

- **ASu (Announcement support) flags:** this 16-bit flag field shall specify the type(s) of announcements by which it is possible to interrupt the reception of the service. The interpretation of this field shall be as defined in TS 101 756 [16], table 14.

The flags shall be coded as follows:

b_i ($i = 0$ to 15);

0: Announcement type not supported;

1: Announcement type supported.

Rfa: this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

Number of clusters: this 5-bit field, coded as an unsigned binary number, shall specify the number of the following Cluster Ids (maximum 23).

Cluster Id: this 8-bit field shall identify the announcement cluster, for which the announcement is intended. From the service point of view the cluster identifies a group of services which share the same announcement interruption privileges. Several cluster Ids may be included in the announcement support field. Cluster Id = "0000 0000" and Cluster Id = "1111 1111" are pre-defined and shall not be signalled in the announcement support field.

Cluster Id = "0000 0000" and Cluster Id = "1111 1111" may be used with the announcement switching information (see clause 8.1.6.2).

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **SId** field.

The Change Event Indication (CEI) is signalled by the **Number of Clusters** field = 0 and the **ASu flags** field = 0.

8.1.6.2 Announcement switching

The announcement switching description is encoded in Extension 19 of FIG type 0 (FIG 0/19). Figure 51 shows the structure of the announcement switching field which is part of the Type 0 field (see also figure 4).

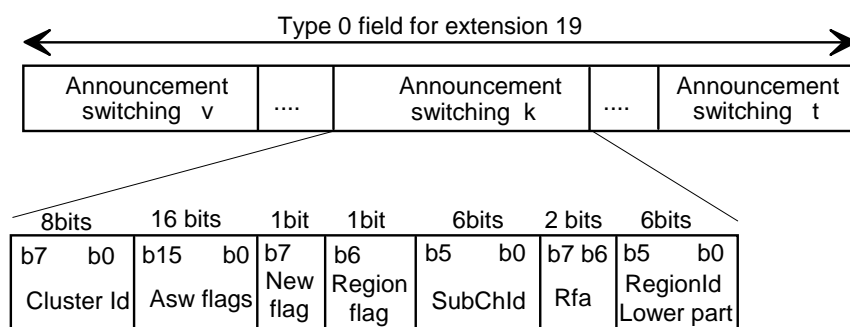


Figure 51: Structure of announcement switching field

The following definitions apply:

Cluster Id: this 8-bit field shall identify the announcement cluster, for which the announcement is intended. Cluster Id = "0000 0000" shall be used for signalling an announcement forming a programme item within the same service. Cluster Id = "1111 1111" shall be used for Alarm announcements and shall be directed to all programme services carried in the ensemble. It shall not be used for any other announcement type.

ASw (Announcement switching) flags: this 16-bit field shall specify the announcement types which apply to the announcement. The individual bits indicate whether or not a particular announcement type is signalled. The interpretation of the flags shall be as defined in TS 101 756 [16], table 14. The flags shall be coded as follows:

b_i ($i = 0$ to 15);

0: Announcement type not valid;

1: Announcement type valid.

New flag: this 1-bit flag shall indicate whether the announcement is newly introduced, as follows:

0: repeated announcement;

1: newly introduced announcement.

Region flag: this 1-bit flag shall indicate whether a region is specified or not, as follows:

0: last byte (the 2-bit Rfa field and the RegionId Lower part field) absent. The announcement concerns the whole service area;

1: last byte (the 2-bit Rfa field and the RegionId Lower part field) present.

SubChId: this 6-bit field shall identify the sub-channel which contains the audio service component carrying the announcement.

Rfa: this 2-bit field shall be reserved for future additions. These bits shall be set to zero until they are defined.

RegionId Lower part: this 6-bit field shall identify the region to which the announcement is targeted. It uses the lower part of the Region Identifier. The upper part of the Region Identifier shall be set to "00000" (see clause 8.1.16).

8.1.7 DRM services

For DRM services, their radio frequencies may be signalled.

8.1.7.1 DRM Frequencies

The frequencies on which DRM services can be found are encoded in extension 21 of the FIG type 0 (FIG 0/21) as described in clause 8.1.8. The OE flag (see clause 5.2.2.1) shall be set to "1".

8.1.8 Frequency Information

The Frequency Information feature is assigned to providing radio Frequency Information (FI). If this applies to the whole tuned ensemble or to a DRM, FM or AM service carrying a Primary service component from the tuned ensemble, the OE flag shall be set to "0" in the FIG type 0 sub-header (see clause 5.2.2.1).

The Frequency Information feature is also used to provide frequencies of ensembles other than the tuned ensemble (R&M = "0000" and "0001"), and of DRM, FM and AM services which are not identical with a primary programme service component from the tuned ensemble (R&M = "0110", "1000", "1001", "1010", "1100" and "1110"). In these cases, the OE flag shall be set to "1" in the FIG type 0 sub-header (see clause 5.2.2.1).

The feature is encoded in Extension 21 of FIG type 0 (FIG 0/21). Figure 52 shows the structure of the FI field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

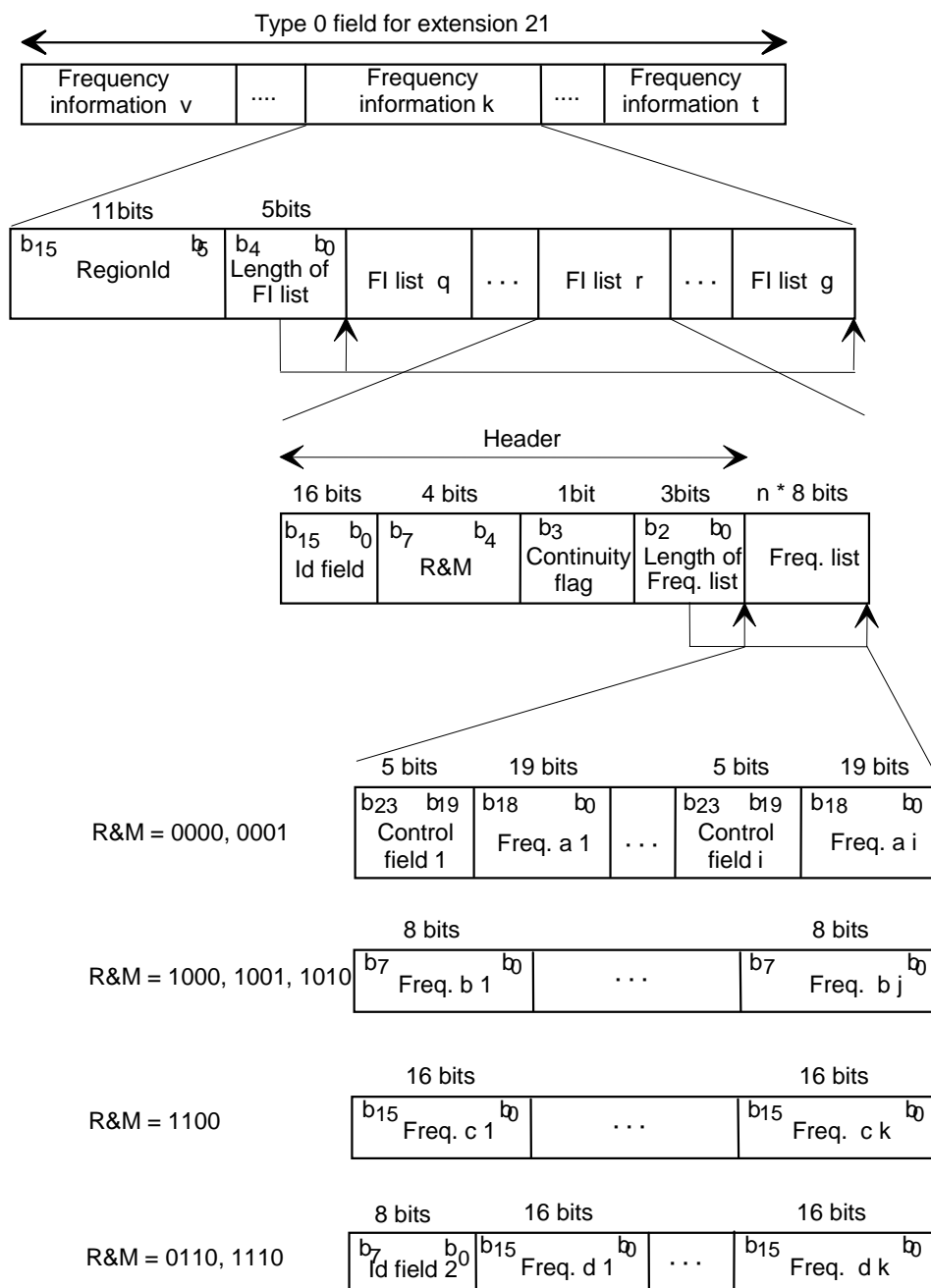


Figure 52: Structure of the Frequency Information field

The following definitions apply:

RegionId: this 11-bit field shall identify the region for which the frequency information applies (see clause 8.1.16).

If the RegionId (see clause 8.1.16) is "0000 0000 000", no area is specified.

Length of FI list: this 5-bit field, expressed as an unsigned binary number, shall represent the length in bytes of the field containing FI list q to FI list g (maximum 26 bytes).

FI (Frequency Information) list:

- **Id field (Identifier field):** this 16-bit field shall depend on the following R&M field, as follows:
 - If R&M = 0000 or 0001 Id field = EId (see clause 6.4);
 - If R&M = 0110 Id field = DRM Service Identifier (two least significant bytes) (see ES 201 980 [18]);

- If R&M = 1000 Id field = RDS PI-code (see EN 62106 [5]);
 - If R&M = 1001, 1010, or 1100 Id field = "Dummy" code.
 - If R&M = 1110 Id field = AMSS Service Identifier (two least significant bytes)
(see TS 102 386 [19]).
- **R&M (Range & Modulation):** this 4-bit field shall define the range and modulation parameters which affect the structure of the alternative frequencies list. The entries marked "Rfu" shall be reserved for future use of the Frequency list field. The coding is as follows:

b₇ - b₄

0 0 0 0: DAB ensemble, no local windows;

0 0 0 1: Rfu;

0 0 1 0: Rfu;

0 0 1 1: Rfu;

0 1 0 0: Rfu;

0 1 0 1: Rfu;

0 1 1 0: DRM;

0 1 1 1: Rfu;

1 0 0 0: FM with RDS;

1 0 0 1: FM without RDS;

1 0 1 0: AM (MW in 9 kHz steps & LW);

1 0 1 1: Rfu;

1 1 0 0: AM (MW in 5 kHz steps & SW);

1 1 0 1: Rfu;

1 1 1 0: AMSS;

1 1 1 1: Rfu.
 - **Continuity flag:** this 1-bit flag shall depend on the R&M field, as follows:
 - If R&M = "0000" or "0001", the continuity flag shall signal that:
 - 0: continuous output not expected;
 - 1: continuous output possible.
 - If R&M = "0110", "1000", "1001", "1010", "1100" or "1110" the continuity flag shall indicate whether, or not, there is an appropriate time delay on the audio signal of an alternative service source on DRM/FM/AM to compensate the decoding time delay of DAB.
 - 0: no compensating time delay on DRM/FM/AM audio signal;
 - 1: compensating time delay on DRM/FM/AM audio signal.
 - For R&M = "0110", "1000", "1001", "1010", "1100" and "1110", the Continuity flag is only valid for OE = "0". For OE = "1", the bit b₃ is reserved for future addition.
 - **Length of Freq. (frequency) list:** this 3-bit field, expressed as an unsigned binary number, shall represent the length in bytes of the following Frequency list field;

- **Freq. (frequency) list:**

The structure of the frequencies list depends on R&M:

- **R&M = 0000, 0001:**

- **Control field:** this 5-bit field shall be used to qualify the immediately following Freq (Frequency) a field. The following functions are defined (the remainder shall be reserved for future use of the Freq a field):

$b_{23} - b_{19}$

0 0 0 0 0: geographically adjacent area, no transmission mode signalled;

0 0 0 1 0: geographically adjacent area, transmission mode I;

0 0 1 0 0: geographically adjacent area, transmission mode II;

0 0 1 1 0: geographically adjacent area, transmission mode III;

0 1 0 0 0: geographically adjacent area, transmission mode IV;

0 0 0 0 1: not geographically adjacent area, no transmission mode signalled;

0 0 0 1 1: not geographically adjacent area, transmission mode I;

0 0 1 0 1: not geographically adjacent area, transmission mode II;

0 0 1 1 1: not geographically adjacent area, transmission mode III;

0 1 0 0 1: not geographically adjacent area, transmission mode IV.

- **Freq (Frequency) a:** this 19-bit field, coded as an unsigned binary number, shall represent the carrier frequency associated with the alternative service source or other service.

The centre carrier frequency of the other ensemble is given by (in this expression, the decimal equivalent of freq a is used):

$0 \text{ Hz} + (\text{Freq a} \times 16 \text{ kHz})$.

The following values of the carrier frequency are defined:

b_{18}	b_0	Decimal	
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0	: Not to be used;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1		1	: 16 kHz;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0		2	: 32 kHz;
" " " " "			
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	524 287		: 8 388 592 kHz.

- **R&M = 0110:**

- **Id field 2:** this 8-bit field represents the DRM Service Identifier (most significant byte) (see ES 201 980 [18]).
- **Rfu:** this 1 bit field shall be reserved for future use of the Freq (Frequency) d field and shall be set to zero until defined.

- **Freq (Frequency) d:** this 15-bit field, coded as an unsigned binary number, shall represent the reference frequency associated with the other service in kHz.

The following values of the reference frequency are defined:

b ₁₄	b ₀	Decimal	
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		0	: Not to be used;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 1		1	: 1 kHz;
0 0 0 0 0 0 0 0 0 0 0 0 0 1 0		2	: 2 kHz;
"	"	"	"
"	"	"	"
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		32 767	: 32 767 kHz.

- **R&M = 1000, 1001, 1010:**

- **Freq (Frequency) b:** this 8-bit field, coded as an unsigned binary number, shall represent the carrier frequency associated with the other service:
- **R&M = 1000, 1001:** the carrier frequency of the FM transmission is given by (in this expression, the decimal equivalent of freq b is used):

$$87,5 \text{ MHz} + (\text{Freq } b \times 100 \text{ kHz}).$$

The following values of the carrier frequency are defined (other values shall be reserved for future use):

b ₇	b ₀	Decimal	
0 0 0 0 0 0 0 0		0	: Not to be used;
0 0 0 0 0 0 0 1		1	: 87,6 MHz;
0 0 0 0 0 0 1 0		2	: 87,7 MHz;
"	"	"	"
1 1 0 0 1 1 0 0		204	: 107,9 MHz.

- **R&M = 1010:** the carrier frequency of the AM transmission is given by (in this expression, the decimal equivalent of freq b is used):

$$144 \text{ kHz} + (\text{Freq } b \times 9 \text{ kHz}) \quad \text{if } \text{Freq } b < 16;$$

$$387 \text{ kHz} + (\text{Freq } b \times 9 \text{ kHz}) \quad \text{if } \text{Freq } b \geq 16.$$

The following values of the carrier frequency are defined (other values shall be reserved for future use):

b ₇	b ₀	Decimal	
0 0 0 0 0 0 0 0		0	: Not to be used;
0 0 0 0 0 0 0 1		1	: 153 kHz;
0 0 0 0 0 0 1 0		2	: 162 kHz;
"	"	"	"
0 0 0 0 1 1 1 1		15	: 279 kHz;
0 0 0 1 0 0 0 0		16	: 531 kHz;
"	"	"	"
1 0 0 0 0 1 1 1		135	: 1 602 kHz.

- **R&M = 1100:**

- **Freq (Frequency) c:** this 16-bit field, coded as an unsigned binary number, shall represent the carrier frequency associated with the other service:

The carrier frequency of the AM transmission is given by (in this expression, the decimal equivalent of freq c is used):

$$0 \text{ Hz} + (\text{Freq c} \times 5 \text{ kHz}).$$

The following values of the carrier frequency are defined:

b ₁₅	b ₀	Decimal	
0 0 0 0	0 0 0 0	0	: Not to be used;
0 0 0 0	0 0 0 0	1	: 5 kHz;
0 0 0 0	0 0 0 0	2	: 10 kHz;
"	"	"	"
1 1 1 1	1 1 1 1	65 535	: 327 675 kHz.

- **R&M = 1110:**

- **Id field 2:** this 8-bit field represents the AMSS Service Identifier (most significant byte) (see TS 102 386 [19]).
- **Rfu:** this 1 bit field shall be reserved for future use of the Freq (Frequency) d field and shall be set to zero until defined.
- **Freq (Frequency) d:** this 15-bit field, coded as an unsigned binary number, shall represent the centre frequency associated with the other service in kHz.

The following values of the reference frequency are defined:

b ₁₄	b ₀	Decimal	
0 0 0	0 0 0 0	0	: Not to be used;
0 0 0	0 0 0 0	1	: 1 kHz;
0 0 0	0 0 0 0	2	: 2 kHz;
"	"	"	"
1 1 1	1 1 1 1	32 767	: 32 767 kHz.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **RegionId**, **Id field**, and **R&M** fields.

The Change Event Indication (CEI) is signalled by the **Length of Freq list** field = 0.

8.1.9 Transmitter Identification Information (TII) database

The Transmitter Identification Information feature provides the cross reference between the transmitter identifiers (see clause 14.8) and the geographic locations and relative time delays of the transmitters. Transmitter identifiers are separated into two groups which are called Main Identifiers (MainId) and Sub-Identifiers (SubId) respectively. Sub-Identifiers 1 to 23 shall be used for terrestrial transmitters. Sub-Identifier 0 is used to indicate satellite transmitters, and shall not be used in this feature. The feature is encoded in Extension 22 of FIG type 0 (FIG 0/22). Figure 53 shows the structure of the TII field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

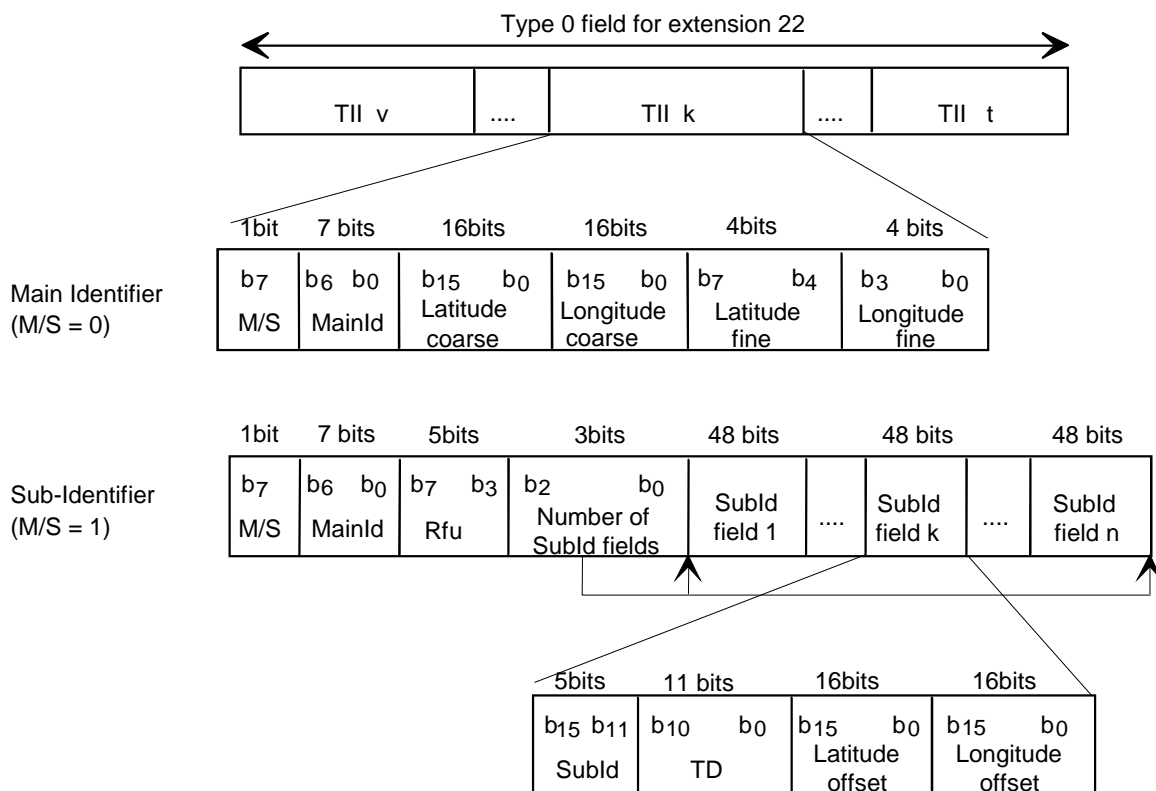


Figure 53: Structure of the Transmitter Identification Information (TII) field

The following definitions apply:

M/S (Main/Sub): this 1-bit flag shall indicate whether the remainder of the TII field refers to a Main Identifier or to a Sub-Identifier, as follows:

0: Main identifier;

1: Sub-identifier.

Main Identifier (M/S = 0):

- **MainId:** this 7-bit field, expressed as an unsigned binary number, shall specify the Main Identifier. The coding range shall be 0 to 69 for transmission modes I, II and IV and 0 to 5 for transmission mode III;
- **Latitude coarse:** this 16-bit field, coded as a two's complement number, shall specify the coarse latitude. It shall be calculated by multiplying the value of the Latitude coarse field by $(90^\circ / 2^{15})$. Southern latitudes shall be considered negative and northern latitudes positive;
- **Longitude coarse:** this 16-bit field, coded as a two's complement number, shall specify the coarse longitude. It shall be calculated by multiplying the value of the Longitude coarse field by $(180^\circ / 2^{15})$. West of Greenwich shall be considered negative and east of Greenwich positive;
- **Latitude fine:** this 4-bit field shall specify the latitude offset. This unsigned binary number multiplied by $(90^\circ / 2^{19})$ shall be added to the coarse latitude to calculate the latitude with full precision;
- **Longitude fine:** this 4-bit field shall specify the longitude offset. This unsigned binary number multiplied by $(180^\circ / 2^{19})$ shall be added to the coarse longitude to calculate the longitude with full precision.

Sub-Identifier (M/S = 1):

- **MainId:** this 7-bit field, coded as an unsigned binary number, shall specify the Main Identifier;
- **Rfu:** this 5-bit field shall be reserved for future use of the field containing the list of SubId fields (as identified by the Number of SubId fields field). The Rfu bits shall be set to zero for the currently specified definition of this associated field;

- **Number of SubId fields:** this 3-bit field, coded as an unsigned binary number, shall give the total number of SubId fields following (maximum 4 of 48-bit each). The information corresponds to successive SubIds.
- **SubId field:**
 - **SubId:** this 5-bit field, coded as an unsigned binary number, shall specify the SubId to which the following data applies. The value zero shall not be used in this field and the coding range of this field is restricted to the values 1 to 23;
 - **TD (Time Delay):** this 11-bit field, coded as an unsigned binary number (in the range 0 to 2 047), shall specify the time delay in microseconds.
 - **Latitude offset:** this 16-bit field, coded as a two's complement number, shall specify the latitude offset of the transmitter from the reference associated with the same MainId. The value of the latitude shall be calculated by adding or subtracting the value of the latitude offset field multiplied by $(90^\circ/2^{19})$ to/from the latitude of the reference;
 - **Longitude offset:** this 16-bit field, coded as a two's complement number, shall specify the longitude offset of the transmitter from the reference associated with the same MainId. The value of the longitude shall be calculated by adding or subtracting the value of the longitude offset field multiplied by $(180^\circ/2^{19})$ to/from the latitude of the reference.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **MainId** field.

The Change Event Indication (CEI) is signalled by the **Number of SubId fields** field = 0.

8.1.10 Other ensembles

The following clauses describe the other ensembles features.

8.1.10.1 OE Frequencies

The other ensembles' frequencies are encoded in Extension 21 of FIG type 0 (see clause 8.1.8). The OE flag (see clause 5.2.2.1) shall be set to "1".

8.1.10.2 OE Services

The OE Services feature is used to identify the services currently carried in other DAB ensembles. The feature is encoded in Extension 24 of FIG type 0 (FIG 0/24). Figure 54 shows the structure of the other ensembles services field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

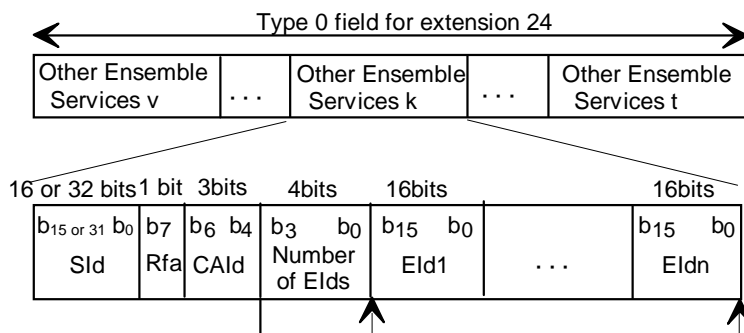


Figure 54: Structure of the other ensembles services field

The following definitions apply:

SId (Service Identifier): this 16-bit or 32-bit field shall identify a service. The coding details are given in clause 6.3.1.

Rfa: this 1-bit field shall be reserved for future additions. The bit shall be set to zero until it is defined.

CAId (Conditional Access Identifier): this 3-bit field shall identify the Access Control System (ACS) used for the service. The definition is given in TS 102 367 [15]. A non-CA capable DAB receiver shall not interpret this field. If no ACS is used for the service, CAId is set to zero.

Number of EIds: this 4-bit field, expressed as an unsigned binary number, shall indicate the number of EIds (maximum 12 for 16-bit SIDs and maximum 11 for 32-bit SIDs) contained in the subsequent list.

EId (Ensemble identifier): this 16-bit code shall identify the ensemble. The coding details are given in clause 6.4.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **SIId** field.

The Change Event Indication (CEI) is signalled by the **Number of EIds** field = 0.

8.1.10.3 OE Programme Number

The other ensembles Programme Number (PNum) feature is encoded in Extension 16 of the FIG type 0 (FIG 0/16) as described in clause 8.1.4. The OE flag (see clause 5.2.2.1) shall be set to "1".

8.1.10.4 OE Programme Type

The other ensembles Programme Type feature is encoded in Extension 17 of the FIG type 0 (FIG 0/17) as described in clause 8.1.5. The OE flag (see clause 5.2.2) shall be set to "1".

8.1.10.5 OE Announcements

The other ensembles announcements feature is encoded in Extensions 25 and 26 of the FIG type 0. (FIG 0/25 and FIG 0/26). Extension 25 is used for the announcement support and Extension 26 is used for the announcement switching (see clause 8.1.6).

8.1.10.5.1 OE Announcement support

Figure 55 shows the structure of the other ensembles Announcement support field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

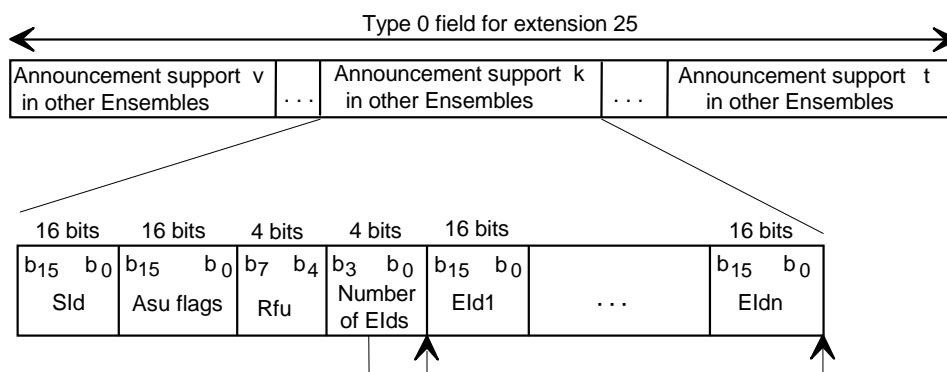


Figure 55: Structure of other ensembles announcement support field

The following definitions apply:

SIId (Service Identifier): this 16-bit field shall identify the service (see clause 6.3.1).

ASu (Announcement support) flags: this 16-bit field shall specify the type of announcements by which a service may be interrupted. The possible values and coding are given in clause 8.1.6.

Rfu: this 4-bit field shall be reserved for future use of the associated field containing the list of EIds (as identified by the Number of EIds field). The Rfu bits shall be set to zero for the currently specified definition of this associated field.

Number of EIDs: this 4-bit field, expressed as an unsigned binary number, shall indicate the number of EIDs (maximum 11) contained in the following list.

EId (Ensemble Identifier): this 16-bit field shall identify the other ensemble. The coding details are given in clause 6.4.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **SI**d field.

The Change Event Indication (CEI) is signalled by the **Number of EIDs** field = 0.

8.1.10.5.2 OE Announcement switching

Figure 51 shows the structure of the other ensembles announcement switching field which is part of the Type 0 field (see also figure 4).

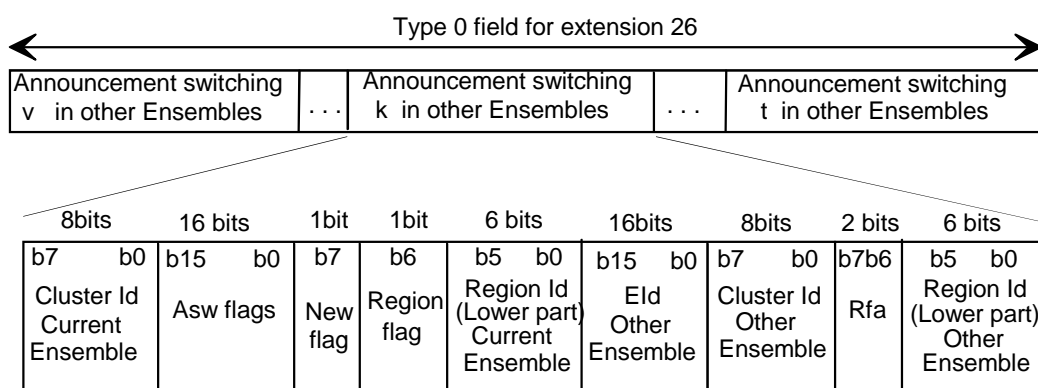


Figure 56: Structure of announcement switching field

The following definitions apply:

Cluster Id Current Ensemble: this 8-bit field shall identify the announcement cluster, in the current ensemble, to which the announcement is intended. ClusterId = "0000 0000" shall not be used.

ASw (Announcement switching) flags: this 16-bit field shall specify the announcement types which apply to the announcement. The individual bits indicate whether or not a particular announcement type is signalled. The possible values and coding are given in clause 8.1.6.

New flag: see clause 8.1.6.2.

Region flag: this 1-bit flag shall indicate whether the last byte is present or not, as follows:

0: last byte [the 2-bit Rfa field and RegionId (Lower part) Other Ensemble] absent. The announcement concerns the whole service area;

1: last byte [the 2-bit Rfa field and RegionId (Lower part) Other Ensemble] present.

RegionId (Lower part) Current Ensemble: this 6-bit field shall identify the region, in the current ensemble, to which the announcement is targeted.

EId Other Ensemble: this 16-bit field shall identify the other ensemble. The coding details are given in clause 6.4.

Cluster Id Other Ensemble: this 8-bit field shall identify the announcement cluster to which the announcement is directed in the other ensemble. ClusterId = "0000 0000" shall not be used.

Rfa: this 2-bit field shall be reserved for future additions. These bits shall be set to zero until defined.

RegionId (Lower part) Other Ensemble: this 6-bit field shall identify the region to which the announcement is targeted in the other ensemble.

8.1.10.6 OE Text labels

Ensemble and service labels associated with other ensembles are encoded in extensions 0, 1 and 5 of FIG type 1 (FIGs 1/0, 1/1 and 1/5) or the FIG type 2 (FIGs 2/0, 2/1 and 2/5), respectively, as described in clauses 8.1.13 and 8.1.14. In each case the OE flag (see clause 5.2.2.2) shall be set to "1".

8.1.11 FM services

The radio frequencies of FM services may be signalled and announcements carried on FM services may be allowed to interrupt DAB services. These features are described in this clause.

8.1.11.1 FM Frequencies

The frequencies on which FM services can be found are encoded in Extension 21 of the FIG type 0 (FIG 0/21) as described in clause 8.1.8. The OE flag (see clause 5.2.2.1) shall be set to "1".

8.1.11.2 FM Announcements

The FM services announcements feature is encoded in Extension 27 and 28 of the FIG type 0. (FIG 0/27 and FIG 0/28). Extension 27 is used for the announcement support and Extension 28 is used for the announcement switching (see clause 8.1.6).

8.1.11.2.1 FM Announcement support

Figure 57 shows the structure of the FM services announcement support field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

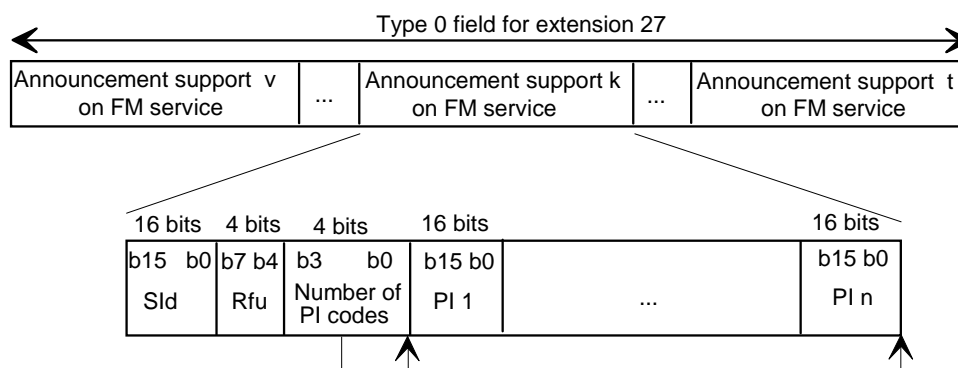


Figure 57: Structure of the FM services announcement support field

The following definitions apply:

SId (Service Identifier): this 16-bit field shall identify the service (see clause 6.3.1).

Rfu: this 4-bit field shall be reserved for future use of the associated PI list. The Rfu bits shall be set to zero for the currently specified definition of this associated field.

Number of PI codes: this 4-bit field, expressed as an unsigned binary number, shall indicate the number of PI codes contained in the following list (maximum 12).

PI (Programme Identification): this 16-bit field shall identify the service carried in the FM channel using the RDS PI code (see EN 62106 [5]).

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **SId** field.

The Change Event Indication (CEI) is signalled by the **Number of PI codes** field = 0.

8.1.11.2.2 FM Announcement switching

Figure 58 shows the structure of the FM services announcement switching field which is part of the Type 0 field (see also figure 4).

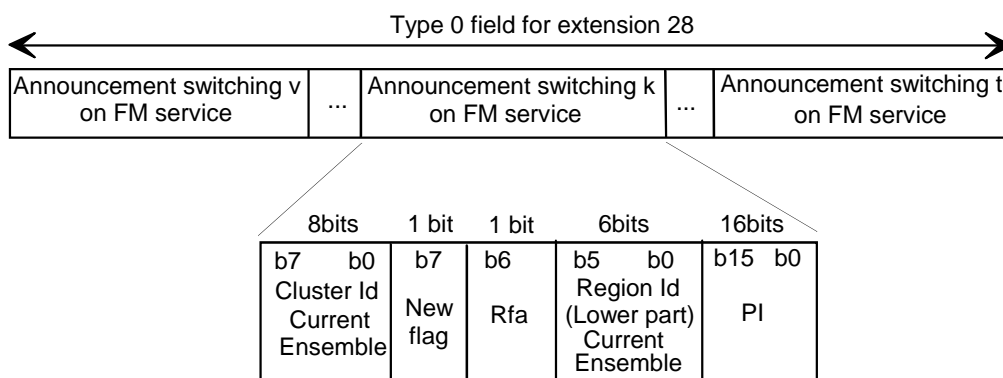


Figure 58: Structure of the FM services announcement switching field

The following definitions apply:

Cluster Id Current Ensemble: this 8-bit field shall identify the announcement cluster, in the current ensemble, to which the announcement is intended. ClusterId = "0000 0000" shall not be used.

New flag: see clause 8.1.6.2.

Rfa: this 1-bit field shall be reserved for future additions. This bit shall be set to zero until it is defined.

RegionId (Lower part) Current Ensemble: this 6-bit field shall identify the region, in the current ensemble, to which the announcement is relayed. "000000" shall indicate that no region is identified and the announcement is directed to the whole ensemble area.

PI (Programme Identification): see clause 8.1.11.2.1.

8.1.11.3 FM Programme Number

The FM services programme number feature is encoded in extension 16 of the FIG type 0 (FIG 0/16) as described in clause 8.1.4. The OE flag (see clause 5.2.2.1) shall be set to "1". The SId field shall be used to signal the RDS PI code (see EN 62106 [5]) or a "dummy" code using the same format.

8.1.11.4 FM Programme Type

The FM services programme type feature is encoded in extension 17 of the FIG type 0 (FIG 0/17) as described in clause 8.1.5. The OE flag (see clause 5.2.2.1) shall be set to "1". The SId field shall be used to signal the RDS PI code (see EN 62106 [5]) or a "dummy" code using the same format.

8.1.11.5 FM Text labels

Service labels associated with FM services are encoded in extension 1 of the FIG type 1 (FIG 1/1) or the FIG type 2 (FIG 2/1) as described in clause 8.1.14. The OE flag (see clause 5.2.2.2) shall be set to "1". The SId field shall be used to signal the RDS PI code (see EN 62106 [5]) or a "dummy" code using the same format.

8.1.12 FIC re-direction

The FIC re-direction feature is used to signal which data features, coded in FIG types 0, 1 and 2, are carried in the Auxiliary Information Channel (AIC). The feature is encoded in Extension 31 of FIG type 0 (FIG 0/31). Figure 59 shows the structure of the FIC overflow signalling field which is part of the Type 0 field (see also figure 4).

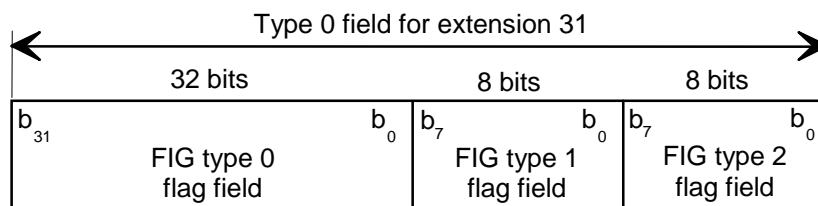


Figure 59: FIC re-direction field

The following definitions apply:

FIG type 0 flag field: this 32-bit field shall indicate which of the 32 Extensions of FIG type 0 are carried in the AIC, as follows:

b_i ($i = 0, \dots, 31$);

0: extension i is not carried in the AIC;

1: extension i is carried in the AIC.

For the FIG type 0 flag field, b_0 to b_5 , b_8 , b_{10} , b_{13} , b_{14} , b_{19} , b_{26} , b_{28} and b_{31} shall be set to "0" because the corresponding information shall always be carried entirely in the FIC.

FIG type 1 flag field: this 8-bit field shall indicate which of the 8 extensions of FIG type 1 are carried in the AIC, as follows:

b_i ($i = 0, \dots, 7$);

0: extension i is not carried in the AIC;

1: extension i is carried in the AIC.

FIG type 2 flag field: this 8-bit field shall indicate which of the 8 extensions of FIG type 2 are carried in the AIC, as follows:

b_i ($i = 0, \dots, 7$);

0: extension i is not carried in the AIC;

1: extension i is carried in the AIC.

When any flags in the FIG type 0 flag field (with the exception of flags b_{21} and b_{24}) or in the FIG type 1 or FIG type 2 flag fields are set to "1" and the OE flag (see clause 5.2.2) is set to "1", the corresponding information may also be carried entirely in the AIC. When any of the flags b_{21} and b_{24} are set to "1", the corresponding information shall be carried in the FIC also but the data repetition rate may be reduced.

When any of the remaining flags in the FIG type 0, the FIG type 1 or the FIG type 2 flag fields is set to "1" and the OE flag is set to "0", the corresponding information shall be carried in the FIC also, but the data repetition rate may be reduced.

8.1.13 Ensemble label

The ensemble label feature is used to identify the ensemble in a textual format. The feature is encoded in Extension 0 of the FIG type 1 (FIG 1/0) and FIG type 2 (FIG 2/0). Figure 60 shows the structure of the Identifier field for the ensemble label which is part of the Type 1 field (see also figure 5) or part of the Type 2 field (see also figure 6). The OE flag (see clause 5.2.2.2) shall be set to "0" for the current ensemble and to "1" for other ensembles.

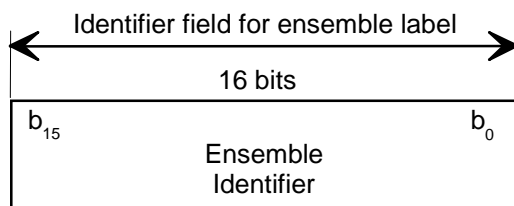


Figure 60: Structure of the Identifier field for the ensemble label

The following definitions apply:

Ensemble Identifier (EId): this 16-bit field shall identify the ensemble. The coding details are given in clause 6.4.

8.1.14 Service label

The Service label feature is used to identify services in a textual format. Programme service, data service, service component labels and X-PAD application type labels are encoded separately.

8.1.14.1 Programme service label

The Programme service label feature is encoded in Extension 1 of the FIG type 1 (FIG 1/1) and FIG type 2 (FIG 2/1). Figure 61 shows the structure of the Identifier field for the service label which is part of the Type 1 field (see also figure 5) or part of the Type 2 field (see also figure 6). The OE flag (see clause 5.2.2.2) shall be set to "0" for the services carried in the current ensemble and set to "1" for services carried in other ensembles.

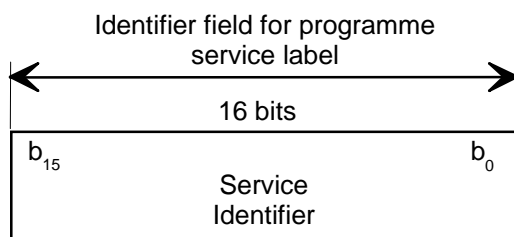


Figure 61: Structure of the Identifier field for the service label

The following definitions apply:

Service Identifier (SId): this 16-bit field shall identify the service (see clause 6.3.1).

8.1.14.2 Data service label

The Data service label feature is encoded in Extension 5 of the FIG type 1 (FIG 1/5) and FIG type 2 (FIG 2/5). Figure 62 shows the structure of the Identifier field for the service label which is part of the Type 1 field (see also figure 5) or part of the Type 2 field (see also figure 6). The OE flag (see clause 5.2.2.2) shall be set to "0" for the services carried in the current ensemble and set to "1" for services carried in other ensembles.

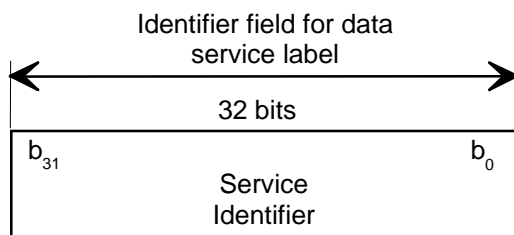


Figure 62: Structure of the Identifier field for the data service label

The following definitions apply:

Service Identifier (SId): this 32-bit field shall identify the service (see clause 6.3.1).

8.1.14.3 Service component label

The Service component label feature is encoded in Extension 4 of FIG type 1 (FIG 1/4) and FIG type 2 (FIG 2/4). Figure 63 shows the structure of the Identifier field for the service component label which is part of the Type 1 field (see also figure 5) or part of the Type 2 field (see also figure 6).

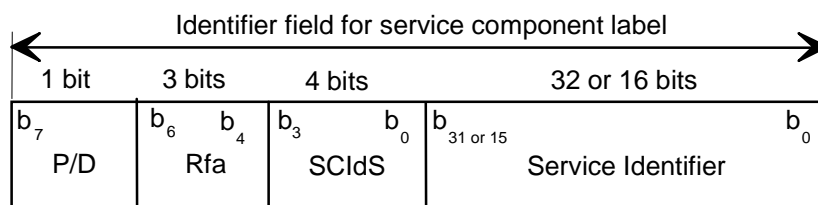


Figure 63: Structure of the Identifier field for the service component label

The following definitions apply:

P/D: this 1-bit flag shall indicate whether the Service Identifier (SIId) field is used for Programme services or Data services, as follows:

- 0: 16-bit SIId, used for Programme services;
- 1: 32-bit SIId, used for Data services.

Rfa: this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

SCIdS (Service Components Identifier within the Service): this 4-bit field shall identify the service component within the service. The combination of the SIId and the SCIdS provides a service component identifier which is valid globally.

Service Identifier (SIId): this 16-bit or 32-bit field shall identify the service. The length of the SIId shall be signalled by the P/D flag, see clause 5.2.2.1.

8.1.14.4 X-PAD user application label

The X-PAD User application label feature is encoded in Extension 6 of FIG type 1 (FIG 1/6) and FIG type 2 (FIG 2/6). Figure 64 shows the structure of the Identifier field for the X-PAD user application label which is part of the Type 1 field (see also figure 5) or part of the Type 2 field (see also figure 6).

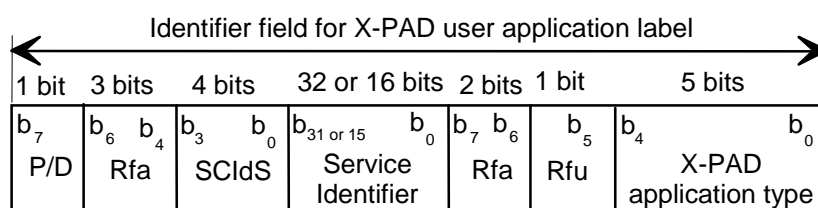


Figure 64: Structure of the Identifier field for the X-PAD user application label

The following definitions apply:

P/D: this 1-bit flag shall indicate whether the Service Identifier (SIId) field is used for Programme services or Data services, as follows:

- 0: 16-bit SIId, used for Programme services;
- 1: 32-bit SIId, used for Data services.

Rfa: this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

SCIdS (Service Components Identifier within the Service): this 4-bit field shall identify the service component within the service. The combination of the SIId and the SCIdS provides a service component identifier which is valid globally.

Service Identifier (SId): this 16-bit or 32-bit field shall identify the service. The length of the SId shall be signalled by the P/D flag, see clause 5.2.2.1.

Rfa: this 2-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined.

Rfu: this 1-bit field shall be reserved for future use of the associated X-PAD application type. The Rfu bits shall be set to zero for the currently specified definition of this associated field.

X-PAD Application Type: this 5-bit field shall specify the application type (see clause 7.4.3).

8.1.15 Service linking information

The Service linking information feature provides service linking information for use when services carry the same primary service component (hard link) or when the primary service components are related (soft link). The feature is encoded in extension 6 of FIG type 0 (FIG 0/6). Figure 65 shows the structure of the service linking field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

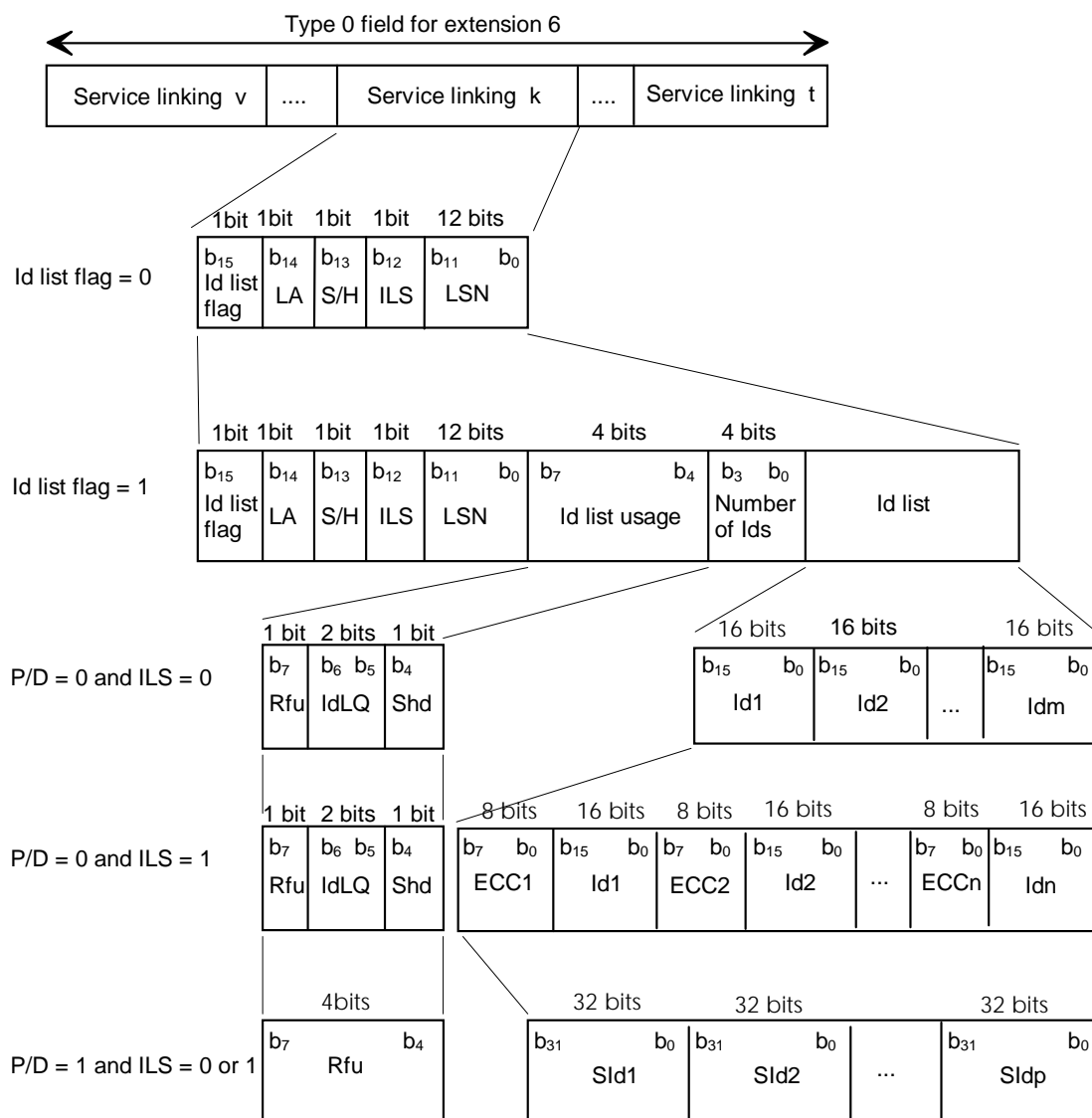


Figure 65: Structure of the Service linking field

The following definitions apply:

Id (Identifier) list flag: this 1-bit flag shall indicate whether the Id list, together with the preceding byte, is present or not, as follows:

0: Id list and the preceding byte absent;

1: Id list and the preceding byte present.

LA (Linkage Actuator): this 1-bit flag shall indicate whether the link is active or inactive (potential), as follows:

0: potential future link or de-activated link;

1: active link.

S/H (Soft/Hard): this 1-bit flag shall indicate whether the link is soft or hard, as follows:

0: Soft link (related services);

1: Hard link (services carrying the same primary service component).

ILS (International linkage set indicator): this 1-bit flag shall indicate whether the link affects only one country (national) or several countries (international), as follows:

0: national link;

1: international link (or DRM or AMSS).

NOTE: If a linkage set includes services broadcast using DRM or AMSS, then the link will always be an international link, even if all linked services are intended for national use.

LSN (Linkage Set Number): this 12-bit field represents a number which shall be common to all Services linked together as a set. The use of LSN = "0000 0000 0000" is reserved.

For an international link, the LSN shall be structured according to EN 62106 [5].

Id list usage (P/D = "0"):

- **Rfu:** this 1-bit field shall be reserved for future use of the Id list qualifier, the Shorthand, the Number of Ids and the Id list fields. The Rfu bit shall be set to zero for the currently specified definition of the associated fields.
- **IdLQ (Identifier List Qualifier):** this 2-bit field shall indicate how the identifiers, contained in the Id list, are qualified, as follows:

$b_6 - b_5$

0 0 : each Id represents a DAB SId (see clause 6.3.1);

0 1 : each Id represents an RDS PI-code (see EN 62106 [5]);

1 0 : each Id represents an AM service or an FM service without RDS;

1 1 : each ECC + Id represents a DRM Service Identifier (see ES 201 980 [18]) or an AMSS Service Identifier (see TS 102 386 [19]).

The IdLQ shall not apply to the first entry in the Id list when OE = "0" and when the version number of the type 0 field is set to "0" (see the Id list definition below).

- **Shd (Shorthand indicator):** this 1-bit flag shall indicate whether each of those programme service identifiers, contained in the Id list and having bits b_{11} to b_8 (see clause 6.3.1) in the range "4" to "F" (expressed as a hexadecimal value), represents a list of up to twelve services sharing the same Country Id and the same eight least significant bits of the Service reference (see clause 6.3.1), as follows:

0: Ids in the Id list represent a single service;

1: Ids in the Id list, having bits b_{11} to b_8 in the range "4" to "F", represent up to twelve services.

Id list usage (P/D = "1"):

- **Rfu:** this 4-bit field shall be reserved for future use of the Number of Ids and the Id list fields. The Rfu bits shall be set to zero for the currently specified definition of the associated fields.

Number of Ids: this 4-bit field, expressed as an unsigned binary number, shall specify the number of identifiers in the Id list (maximum 12 when P/D = 0 and ILS = 0, maximum 8 when P/D = 0 and ILS = 1 and maximum 6 when P/D = 1).

Id list (P/D = "0"):

- **Id (Identifier of Service):** this 16-bit field shall identify the programme service, depending on the Id list qualifier field and the shorthand flag. When the Id list qualifier = "11", the Id field shall carry the two least significant bytes of the DRM or AMSS Service Identifier.
- **ECC (Extended Country Code):** this 8-bit field, together with the Country Id part of the SId, shall identify the country to which the Service belongs (see clause 8.1.3). When the Id list qualifier = "11", the ECC shall carry the most significant byte of the DRM or AMSS Service Identifier.

Id list (P/D = "1"):

- **SId (Service Identifier):** this 32-bit field shall identify the data service (see clause 6.3.1).

When the list of all the services, that are associated with the link, includes an SId, that applies to a service carried in the ensemble, the OE flag (see clause 5.2.2.1) shall be set to "0". In this case (OE = "0") and when the version number of the type 0 field is set to "0" (using the C/N flag, see clause 5.2.2.1), the first entry in the Id list of each Service linking field shall be the SId that applies to the service in the ensemble.

When the list of all the services, that are associated with the link, does not include a reference to a service carried in the ensemble, the OE flag shall be set to "1". In this case, there is no preferred order for the identifiers in the list.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **S/H**, **ILS**, and **LSN** fields.

The Change Event Indication (CEI) is signalled by the **Id List flag** = 0.

8.1.16 Regional identification

The Regional identification feature is used to define geographical regions and provide textual labels to identify them.

8.1.16.1 Region definition

The Region definition feature defines the geographical area by providing the cross reference between a Region Identifier and a TII list, and optionally geographical co-ordinates. The geographical area shall always be defined in terms of a TII list (GATy = "0000"), regardless of whatever other means of definition is also signalled (GATy ≠ "0000"). The feature is encoded in extension 11 of FIG type 0 (FIG 0/11). Figure 66 shows the structure of the Region definition field which is part of the Type 0 field (see also figure 4).

This feature shall use the SIV signalling (see clause 5.2.2.1). The database shall be divided by use of a database key. Changes to the database shall be signalled using the CEI.

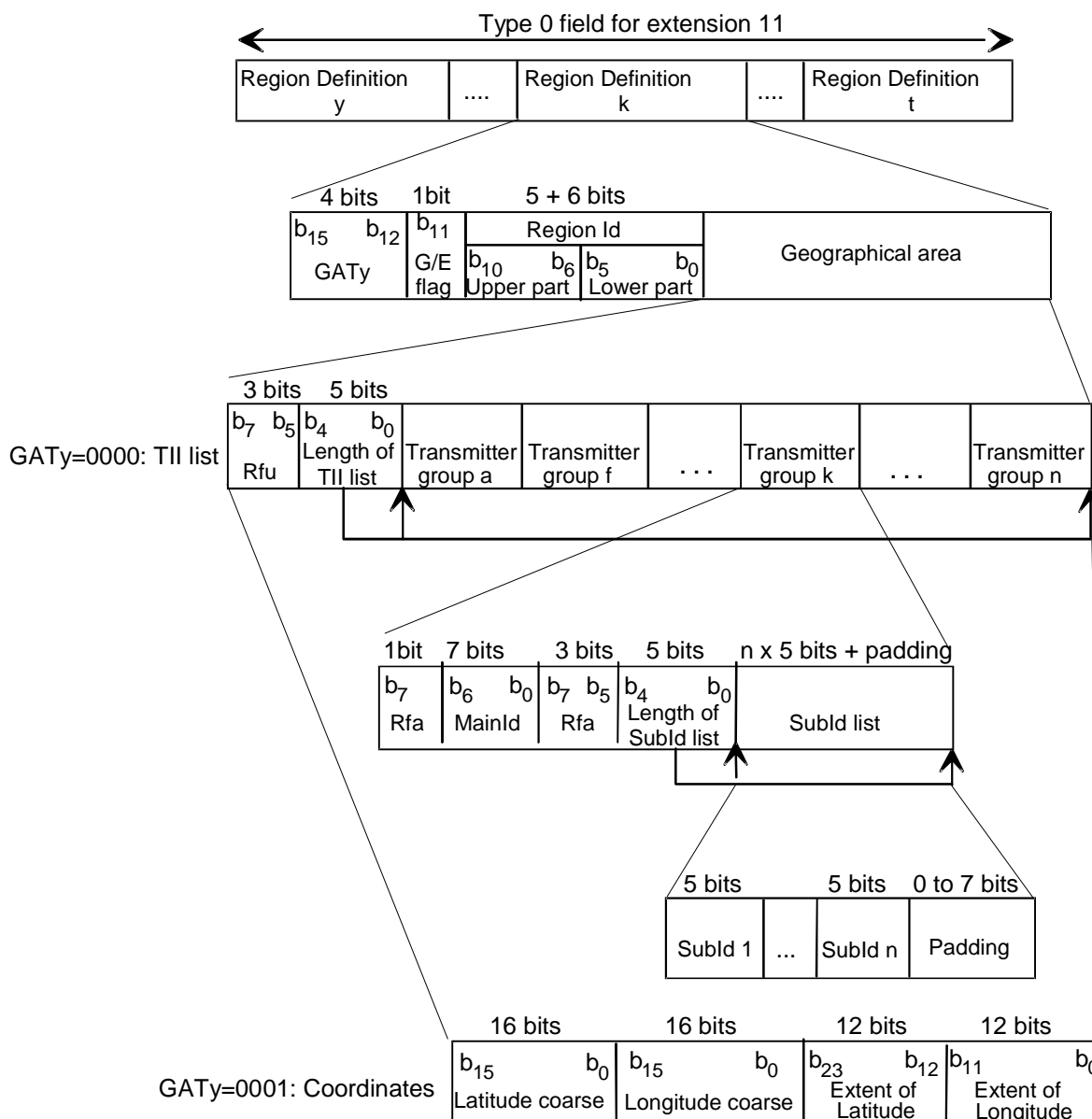


Figure 66: Structure of region definition information

The following definitions apply:

GATy (Geographical Area Type): this 4-bit field shall indicate the coding method for the geographical area. The following values of the GATy field are defined (the remaining values are reserved for future use of the geographical area field). In all further cases, the length of the geographical area field shall be defined by a byte length indicator contained within the first byte of the field and encoded in the same way as in the case GATy = "0000"):

$b_{15} - b_{12}$

0 0 0 0 : Geographical area defined by a TII list;

0 0 0 1 : Geographical area defined as a spherical rectangle by the geographical co-ordinates of one corner and its latitude and longitude extents.

G/E (Global/Ensemble) flag: this 1-bit field shall determine the coverage area over which the RegionId is defined as follows:

0: Ensemble coverage area;

1: Global coverage area (area defined by CountryId + ECC).

RegionId (Region identifier): this 11-bit field, organized as a 5-bit **upper part** and a 6-bit **lower part**, shall identify the region. The value RegionId = "000...0" is reserved (see clause 8.1.8).

Geographical area: this field defines the area of the region in terms of a TII list or a rectangle based on co-ordinates.

TII list: this field defines the geographical area in terms of the service area of all transmitters identified in the list:

- **Rfu:** this 3-bit field shall be reserved for future use of the associated geographical area field excluding the first byte. The Rfu bit shall be set to "0" for the currently specified definition of this associated field;
- **Length of TII list:** this 5-bit field, expressed as an unsigned binary number, shall represent the length in bytes (maximum 25) of the TII list field, excluding the byte in which this length parameter is carried.

The definitions below apply to one transmitter group sharing a main identifier:

- **Rfa:** this 1-bit field shall be reserved for future additions. The bit shall be set to "0" until it is defined;
- **MainId (Main Identifier):** this 7-bit field, expressed as an unsigned binary number, shall identify a group of transmitters (see clause 8.1.9);
- **Rfa:** this 3-bit field shall be reserved for future additions. The bits shall be set to zero until they are defined;
- **Length of SubId list:** this 5-bit field, expressed as an unsigned binary number, shall represent the length in bytes (maximum 23) of the SubId list field. The length "00000" shall be reserved for future use;
- **SubId list:** this list shall contain a number of SubIds. Padding bits (0 to 7) shall be added for byte alignment;
- **SubId:** this 5-bit field, expressed as an unsigned binary number, shall signal a Sub-identifier associated with a transmitter (see clause 8.1.9);
- **Padding:** this field shall contain sufficient bits in the range 0 to 7 to make up the overall length of each SubId list field to an integral number of bytes. Padding bits shall be set to "0".

Co-ordinates: this field defines the geographical area in terms of a rectangle based on co-ordinates.

- **Latitude coarse:** this 16-bit field, coded as a two's complement number, shall specify the coarse latitude of a corner of the spherical rectangle that defines the area. It shall be calculated by multiplying the value of the Latitude coarse field by $(90^\circ / 2^{15})$. Southern latitudes shall be considered negative and northern latitudes positive;
- **Longitude coarse:** this 16-bit field, coded as a two's complement number, shall specify the coarse longitude of a corner of the spherical rectangle that defines the area. It shall be calculated by multiplying the value of the Longitude coarse field by $(180^\circ / 2^{15})$. West of Greenwich shall be considered negative and east of Greenwich positive;
- **Extent of Latitude:** this 12-bit field, coded as an unsigned binary number, shall specify the extent of latitude of the spherical rectangle that defines the area. It shall be calculated by multiplying the value of the extent of Latitude field by $(90^\circ / 2^{15})$;
- **Extent of Longitude:** this 12-bit field, coded as an unsigned binary number, shall specify the extent of longitude of the spherical rectangle that defines the area. It shall be calculated by multiplying the value of the extent of Longitude field by $(180^\circ / 2^{15})$.

The database key comprises the **OE** and **P/D** flags (see clause 5.2.2.1) and the **RegionId** field.

The Change Event Indication (CEI) is signalled by the **Length of TII list** field = 0.

8.1.19.4 AM Text labels

Service labels associated with AM services are encoded in extension 1 of the FIG type 1 (FIG 1/1) or the FIG type 2 (FIG 2/1) as described in clause 8.1.14. The OE flag (see clause 5.2.2.2) shall be set to "1".

8.1.20 User application information

User application information provides signalling to allow data applications to be associated with the correct user application decoder by the receiver.

The user application information feature is encoded in extension 13 of FIG type 0 (FIG 0/13). Figure 68 shows the structure of the user application information field which is part of the Type 0 field (see also figure 4). It associates information about where the data is carried (packet or stream mode sub-channels, X-PAD or FIDC) with a registered application identifier, and also allows a limited amount of application specific information to be signalled.

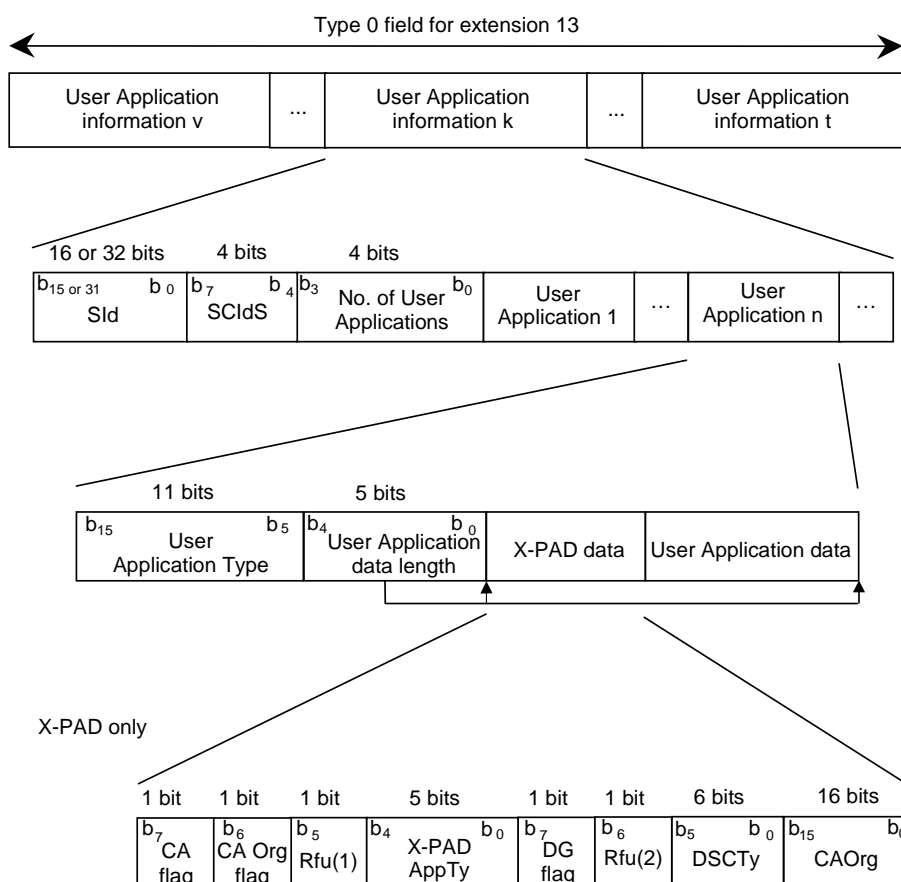


Figure 68: Structure of the user application field

The following definitions apply:

SId (Service Identifier): this 16-bit or 32-bit field shall identify the service (see clause 6.3.1) and the length of the SId shall be signalled by the P/D flag (see clause 5.2.2.1).

SCIdS (Service Component Identifier within the Service): this 4-bit field shall identify the service component within the service. The combination of the SId and the SCIdS provides a globally valid identifier for a service component.

Number of user applications: this 4-bit field, expressed as an unsigned binary number, shall indicate the number of user applications (in the range 1 to 6) contained in the subsequent list.

User Application Type: this 11-bit field identifies the user application that shall be used to decode the data in the channel identified by SId and SCIdS. The interpretation of this field shall be as defined in TS 101 756 [16], table 16.

User Application data length: this 5-bit field, expressed as an unsigned binary number (in the range 0 to 23), indicates the length in bytes of the X-PAD data field (when present) and User Application data field that follows.

X-PAD data: this field is only present for applications carried in the X-PAD of an MSC stream audio service component.

- **CA flag:** this 1-bit field shall indicate whether access control applies to the user application, or not, as follows:
 - 0: no access control or access control applies only to a part of the user application;
 - 1: access control applies to the whole of the user application.
- Every DAB receiver shall check the "CA flag". A non-CA capable DAB receiver shall not try to decode the user application if the "CA flag" is set to 1.
- **CAOrg flag:** this 1-bit field shall indicate whether the Conditional Access Organization (CAOrg) field is present, or not, as follows:
 - 0: CAOrg field absent;
 - 1: CAOrg field present.
- **Rfu(1):** this 1-bit field shall be reserved for future use of the associated X-PAD application type. This bit shall be set to zero for the currently specified definition of the associated field.
- **X-PAD Application Type:** this 5-bit field shall specify the lowest numbered application type used to transport this user application (see clause 7.4.3).
- **DG flag:** this 1-bit flag shall indicate whether MSC data groups are used to transport the user application as follows:
 - 0: MSC data groups are used to transport the user application;
 - 1: MSC data groups are not used to transport the user application.
- **Rfu(2):** this 1-bit field shall be reserved for future use of the DSCTy field. The Rfu bit shall be set to zero for the currently specified definition of this field.
- **DSCTy (Data Service Component Type):** see clause 6.3.1.
- **CAOrg (Conditional Access Organization):** this 16-bit field shall contain information about the Conditional Access Systems and mode (see TS 102 367 [15]).

User Application data: these 8-bit fields may be used to signal application specific information. The interpretation of these fields is determined by the user application identified by the User Application Type.

NOTE: Transmission equipment conforming to previous versions of the present document may provide FIG 0/13 signalling but without using the X-PAD data field. This is detectable by receivers because the User application data length field has a value of 0 or 1. In this case the receiver should use default values for the X-PAD data sub-fields as follows: CA flag = 0; CAOrg flag = 0; X-PAD application type = 12; DG flag = 0; DSCTy = Multimedia Object Transfer (MOT) (see TS 101 756 [16]).

8.2 Fast Information Data Channel

This clause defines the data service components which may be transported in the Fast Information Data Channel (FIDC) within the FIC. The FIDC uses FIG type 5 (see figure 7).

8.2.1 Paging

The paging feature is encoded in Extension 0 of FIG type 5 (FIG 5/0). A pointer mechanism is used to indicate where the paging information may be carried in the Main Service Channel. Figure 69 shows the structure of the paging field which is part of the Type 5 field (see also figure 7).

The following definitions apply to the flags D_1 and D_2 defined in clause 5.2.2.3:

D1: this 1-bit flag shall signal two definitions of the Type 5 field (see figure 7), as follows:

- 0: paging messages in an integral number of bytes;
- 1: pointer - see below.

D2: this 1-bit flag shall signal whether the paging messages are scrambled (see TS 102 367 [15]), as follows:

- 0: not scrambled according to configuration 2;
- 1: scrambled according to configuration 2.

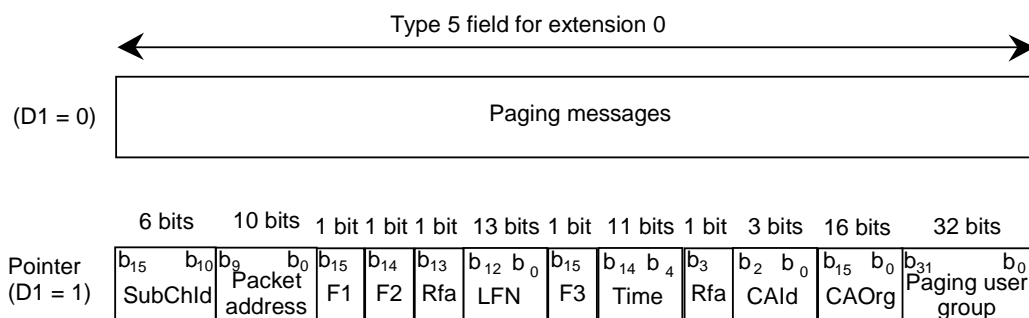


Figure 69: Structure of the paging field

The following definitions apply:

Paging Messages: this field shall contain the paging messages.

SubChId (Sub-channel Identifier): this 6-bit field shall identify the sub-channel to which the paging information is directed (see clause 6.2).

Packet address: this 10-bit field shall identify the address of the packets, carrying the paging data.

F1: this 1-bit flag shall indicate whether the following F_3 flag, time, CAId and CAOrg fields are present, or not, as follows:

- 0: F_3 flag, time, CAId and CAOrg fields absent;
- 1: F_3 flag, time, CAId and CAOrg fields present.

F2: this 1-bit flag shall indicate whether the following time field and LFN applies to the beginning or the end of the service broadcast:

- 0: begin of the service broadcast;
- 1: end of the service broadcast.

Rfa: this 1-bit field shall be reserved for future additions. The bit shall be set to "0" until it is defined.

LFN (Logical Frame Number): this 13-bit field, expressed as an unsigned binary number, shall contain the logical frame count which indicates the number of the logical frame from which the broadcast of the service component will start or end.

The value "1FFF" (hex) shall be reserved to indicate that the LFN is not effective.

F3: this 1-bit flag shall indicate whether the time field, if present, is effective, or not, as follows:

0: time field effective;

1: time field not effective.

Time: this 11-bit field shall indicate the time from which the emission of the service component will start or end. The time field shall be coded in the short form of the UTC as described in clause 8.1.3.1.

Rfa: this 1-bit field shall be reserved for future additions. The bit shall be set to zero until it is defined.

CAId (Conditional Access Identifier): this 3-bit field shall identify the Access Control System (ACS) used for the service. The definition is given in TS 102 367 [15]. A non-CA capable DAB receiver shall not interpret this field. If no ACS is used for the service, CAId shall be set to zero.

CAOrg (Conditional Access Organization): this 16-bit field shall contain information about the applied Conditional Access Systems and mode (see TS 102 367 [15]).

Paging user group: this 32-bit field shall be used to identify the receivers to which the new paging service is directed.

8.2.2 Traffic Message Channel (TMC)

Traffic messages are encoded in Extension 1 of FIG type 5 (FIG 5/1) see TS 102 368 [17].

8.2.3 Emergency Warning Systems (EWS)

The Emergency Warnings Systems (EWS) feature (see EN 62106 [5]) is encoded in Extension 2 of FIG type 5 (FIG 5/2). Figure 70 shows the structure of the EWS field which is part of the Type 5 field (see also figure 7).

The following definitions apply to the flags D1 and D2 (see clause 5.2.2.3):

D1: this 1-bit flag shall be reserved for future use of the Type 5 field (see figure 7).

D2: this 1-bit flag shall signal whether the Type 5 field (see figure 7) contains receiver control information or messages, as follows:

0: control information;

1: messages.

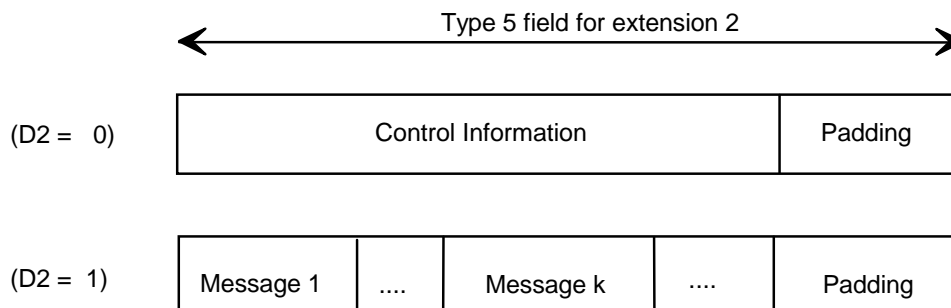


Figure 70: Structure of Emergency Warning System field

The following definitions apply:

Control Information: this field shall contain control information for EWS receivers.

Padding: this field shall contain sufficient bits in the range 0 to 7 to make up the length to an integral number of bytes. The padding bits shall be set to "0".

Message: this field shall contain an EWS message.

9 Conditional Access (CA)

The Conditional Access system used in the DAB system is specified in TS 102 367 [15].

10 Energy dispersal

10.1 General procedure

In order to ensure appropriate energy dispersal in the transmitted signal, the individual inputs of the energy dispersal scramblers shown in figure 1 shall be scrambled by a modulo-2 addition with a pseudo-random binary sequence (PRBS), prior to convolutional encoding.

The PRBS shall be defined as the output of the feedback shift register of figure 71. It shall use a polynomial of degree 9, defined by:

$$P(X) = X^9 + X^5 + 1$$

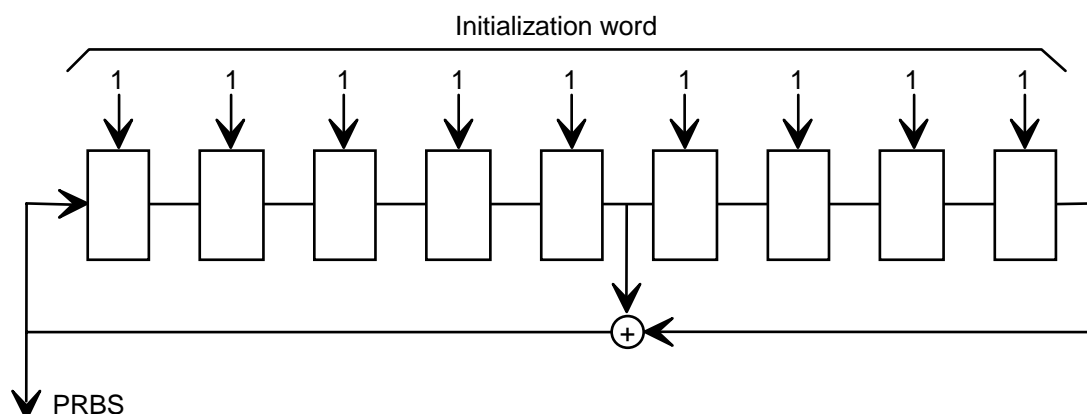


Figure 71: PRBS generator

The initialization word shall be applied in such a way that the first bit of the PRBS is obtained when the outputs of all shift register stages are set to value "1". The first 16 bits of the PRBS are given in table 28.

Table 28: First 16 bits of the PRBS

bit index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
bit value	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0

10.2 Energy dispersal as applied in the Fast Information Channel

The FIBs defined in clause 5.2.1 shall be processed by the energy dispersal scrambler as follows.

Transmission modes I, II and IV

The 3 FIBs corresponding to one CIF shall be grouped together at the output of the Fast Information Block assembler to form a 768-bit vector. This vector shall be a juxtaposition of the 3 FIBs, the first bit of this vector being the first bit of the first FIB.

This vector shall be scrambled with the PRBS, the first bit of the vector being added modulo 2 to the PRBS bit of index 0.

Transmission mode III

The 4 FIBs corresponding to one CIF shall be grouped together at the output of the Fast Information Block (FIB) assembler to form a 1 024-bit vector. This vector shall be a juxtaposition of the 4 FIBs, the first bit of this vector being the first bit of the first FIB.

This vector shall be scrambled with the PRBS, the first bit of the vector being added modulo 2 to the PRBS bit of index 0.

10.3 Energy dispersal as applied in the Main Service Channel

The content of each logical frame (see clause 5.3.1) at the output of the SI packet multiplex assembler, and at the output of each CA scrambler, as shown in figure 1, shall be scrambled in such a way that the first bit of each logical frame associated with a given sub-channel shall be added modulo 2 to the PRBS bit of index 0.

11 Convolutional coding

The channel encoding process is based on punctured convolutional coding, which allows both equal and Unequal Error Protection (UEP), matched to bit error sensitivity characteristics.

This process is applied to the output of each energy dispersal scrambler. The output of a scrambler is denoted as a vector $(a_i)_{i=0}^{I-1}$ of I bits during any given logical frame.

Clause 11.1 defines the general encoding procedure. Clauses 11.2 and 11.3 define the particular application of the encoding procedure in the FIC and in the MSC.

11.1 Convolutional code

11.1.1 Mother code

The channel coding is based on a convolutional code with constraint length 7. The mother convolutional encoder generates from the vector $(a_i)_{i=0}^{I-1}$ a codeword $\{(x_{0,i}, x_{1,i}, x_{2,i}, x_{3,i})\}_{i=0}^{I+5}$. This codeword shall be defined by:

$$x_{0,i} = a_i \oplus a_{i-2} \oplus a_{i-3} \oplus a_{i-5} \oplus a_{i-6};$$

$$x_{1,i} = a_i \oplus a_{i-1} \oplus a_{i-2} \oplus a_{i-3} \oplus a_{i-6};$$

$$x_{2,i} = a_i \oplus a_{i-1} \oplus a_{i-4} \oplus a_{i-6};$$

$$x_{3,i} = a_i \oplus a_{i-2} \oplus a_{i-3} \oplus a_{i-5} \oplus a_{i-6};$$

for $i = 0, 1, 2, \dots, I+5$.

When i does not belong to the set $\{0, 1, 2, \dots, I-1\}$, a_i shall be equal to zero by definition.

The encoding can be achieved using the convolutional encoder presented in figure 72.

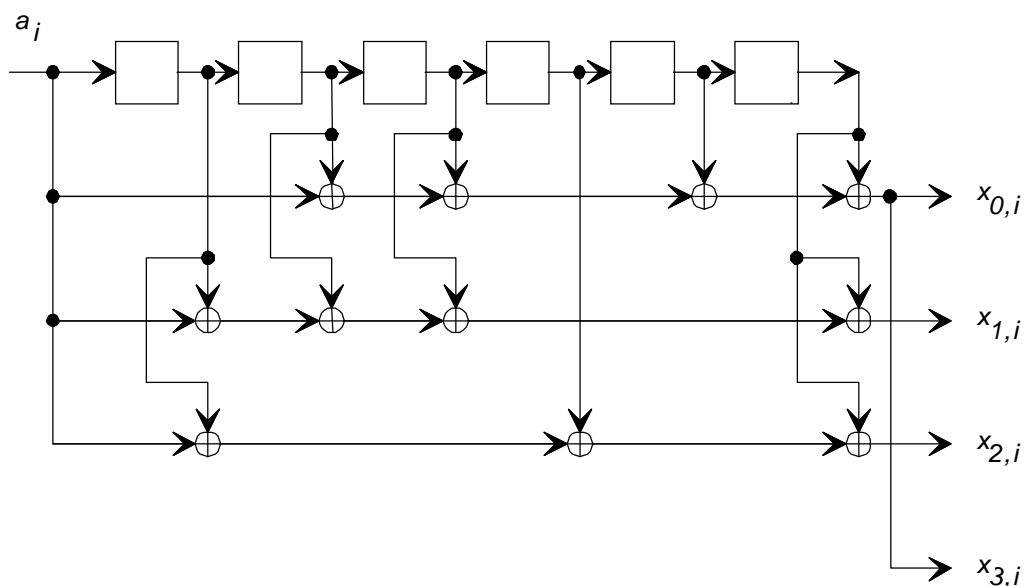


Figure 72: Convolutional encoder

The octal forms of the generator polynomials are 133, 171, 145 and 133, respectively.

The vector $(a_{-6}, a_{-5}, a_{-4}, a_{-3}, a_{-2}, a_{-1})$ corresponds to the all-zero initial state of the shift register and the vector $(a_I, a_{I+1}, a_{I+2}, a_{I+3}, a_{I+4}, a_{I+5})$ corresponds to the all-zero final state of the shift register.

Each codeword $\{(x_{0,i}, x_{1,i}, x_{2,i}, x_{3,i})\}_{i=0}^{I+5}$ is ordered as a serial mother codeword U with:

$$(u_0, u_1, u_2, \dots, u_{4I-1});$$

and

$$u_i = x_{R(\frac{i}{4})} Q(\frac{i}{4}) \text{ for } i = 0, 1, 2, \dots, 4I + 23.$$

The functions R and Q, denoting the remainder and the quotient of a division, respectively, are defined in clause 3.3.

11.1.2 Puncturing procedure

Punctured convolutional coding shall be applied; some predefined codebits generated by the mother code are not transmitted.

The first $4I$ bits $(u_0, u_1, u_2, \dots, u_{4I-1})$ of the serial mother codeword U shall be split into consecutive blocks of 128 bits.

Each block shall be divided into four consecutive sub-blocks of 32 bits. All sub-blocks belonging to the same block shall be punctured using the same rule, given by the value of the puncturing index PI .

Each index PI corresponds to a puncturing vector V_{PI} , denoted by:

$$V_{PI} = (v_{PI,0}, v_{PI,1}, \dots, v_{PI,i}, \dots, v_{PI,31}).$$

The $(i + 1)^{th}$ bit ($i = 0, 1, 2, \dots, 31$) in each sub-block is processed according to the value of the element $v_{PI,i}$ of the puncturing vector V_{PI} , in the following way:

- for $v_{PI,i} = 0$, the corresponding bit shall be taken out of the sub-block and shall not be transmitted;
- for $v_{PI,i} = 1$, the corresponding bit shall be retained in the sub-block and shall be transmitted.

The values of the puncturing vectors are given in table 29.

In table 29, the value of the code rate (equal to $\frac{8}{8+PI}$) is also indicated.

Table 29: Puncturing vectors

	$(v_{PI,0}, \dots, \dots, v_{PI,31})$
PI=1: code rate: 8/9	1100 1000 1000 1000 1000 1000 1000 1000
PI=2: code rate: 8/10	1100 1000 1000 1000 1100 1000 1000 1000
PI=3: code rate: 8/11	1100 1000 1100 1000 1100 1000 1000 1000
PI=4: code rate: 8/12	1100 1000 1100 1000 1100 1000 1100 1000
PI=5: code rate: 8/13	1100 1100 1100 1000 1100 1000 1100 1000
PI=6: code rate: 8/14	1100 1100 1100 1000 1100 1100 1100 1000
PI=7: code rate: 8/15	1100 1100 1100 1100 1100 1100 1100 1000
PI=8: code rate: 8/16	1100 1100 1100 1100 1100 1100 1100 1100
PI=9: code rate: 8/17	1110 1100 1100 1100 1100 1100 1100 1100
PI=10: code rate: 8/18	1110 1100 1100 1100 1110 1100 1100 1100
PI=11: code rate: 8/19	1110 1100 1110 1100 1110 1100 1100 1100
PI=12: code rate: 8/20	1110 1100 1110 1100 1110 1100 1110 1100
PI=13: code rate: 8/21	1110 1110 1110 1100 1110 1100 1110 1100
PI=14: code rate: 8/22	1110 1110 1110 1100 1110 1110 1110 1100
PI=15: code rate: 8/23	1110 1110 1110 1110 1110 1110 1110 1100
PI=16: code rate: 8/24	1110 1110 1110 1110 1110 1110 1110 1110
PI=17: code rate: 8/25	1111 1110 1110 1110 1110 1110 1110 1110
PI=18: code rate: 8/26	1111 1110 1110 1110 1111 1110 1110 1110
PI=19: code rate: 8/27	1111 1110 1111 1110 1111 1110 1110 1110
PI=20: code rate: 8/28	1111 1110 1111 1110 1111 1110 1111 1110
PI=21: code rate: 8/29	1111 1111 1111 1110 1111 1110 1111 1110
PI=22: code rate: 8/30	1111 1111 1111 1110 1111 1111 1111 1110
PI=23: code rate: 8/31	1111 1111 1111 1111 1111 1111 1111 1110
PI=24: code rate: 8/32	1111 1111 1111 1111 1111 1111 1111 1111

The last 24 bits of the serial mother codeword, $(u_{4I}, u_{4I+1}, u_{4I+2}, \dots, u_{4I+23})$, shall be punctured using the puncturing vector given by:

$$\mathbf{V}_T = (1100 1100 1100 1100 1100 1100).$$

The resulting 12 bits are called tail bits.

The four punctured sub-blocks originating from each 128-bit block shall then be grouped together into a block of length $4(8+PI)$ bits. All these blocks shall then be grouped together and the tail bits shall be appended to the last block. The order of the sub-blocks and blocks shall be retained.

The resulting word is called a punctured codeword.

To ensure a word length of a multiple of 64 bits at the output of the encoding process, it shall be necessary for certain puncturing schemes to append "zero value" padding bits at the end of the punctured codeword, as specified in the following clauses.

The resulting word is called a convolutional codeword.

11.2 Coding in the Fast Information Channel

This clause defines the encoding procedure applied in the Fast Information Channel (FIC).

11.2.1 Transmission modes I, II, and IV

Each 768-bit vector $(a_i)_{i=0}^{767}$ at the output of the energy dispersal scrambler (see clause 10.2) shall be processed as defined in clause 11.1.1.

The first $4I = 3\ 072$ bits of the serial mother codeword U shall be split into 24 consecutive blocks of 128 bits, as defined in clause 11.1.2.

The first 21 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index $PI = 16$.

The remaining 3 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index $PI = 15$.

This corresponds to a code rate of approximately 1/3.

Finally, the last 24 bits of the serial mother codeword shall be punctured as defined in clause 11.1.2. No padding bits shall be added.

The resulting convolutional codeword is denoted $(b_i)_{i=0}^{2\ 303}$.

11.2.2 Transmission mode III

Each 1 024-bit vector $(a_i)_{i=0}^{1\ 023}$ at the output of the energy dispersal scrambler (see clause 10.2) shall be processed as defined in clause 11.1.1.

The first $4I = 4\ 096$ bits of the serial mother codeword U shall be split into 32 consecutive blocks of 128 bits, as defined in clause 11.1.2.

The first 29 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index $PI = 16$.

The remaining 3 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index $PI = 15$.

This corresponds to a code rate of approximately 1/3.

Finally, the last 24 bits of the serial mother codeword shall be punctured as defined in clause 11.1.2. No padding bits shall be added.

The resulting convolutional codeword is denoted $(b_i)_{i=0}^{3\ 071}$.

11.3 Coding in the Main Service Channel

In this clause the details of the puncturing procedure are specified in terms of protection profiles and protection levels. A protection profile associates the various blocks of a mother codeword with a collection of puncturing indices. For each of the allowed values of the audio or data bit rate a number of permissible protection profiles are defined. The set of protection profiles allows for audio and data broadcasting over radio frequency channels or cable networks with a level of protection suited to the requirements of the transmission channel.

Each protection profile is associated with a protection level indicating the relative level of protection provided. Protection level 1 indicates the highest level of protection within each set of profiles. The protection levels defined in clauses 11.3.1 and 11.3.2 (set A and set B) are independent of each other.

11.3.1 Unequal Error Protection (UEP) coding

Each logical frame at the output of the energy dispersal scrambler (according to clause 10.3) corresponding to the processing of an audio service component, consists of a I -bit vector $(a_i)_{i=0}^{I-1}$, where I is a function of the audio bit rate.

NOTE: UEP profiles are designed for audio, but the use of UEP profiles for other applications is not excluded.

Each vector $(a_i)_{i=0}^{I-1}$ shall be processed as defined in clause 11.1.1. The first $4I$ bits of the serial mother codeword U are split into L consecutive blocks of 128 bits, as defined in clause 11.1.2.

The value of L for each possible audio bit rate shall comply with table 30.

Table 30: Correspondence between the audio bit rates and the parameters I and L

Audio bit rate (kbit/s)	I	L
32	768	24
48	1 152	36
56	1 344	42
64	1 536	48
80	1 920	60
96	2 304	72
112	2 688	84
128	3 072	96
160	3 840	120
192	4 608	144
224	5 376	168
256	6 144	192
320	7 680	240
384	9 216	288

The first L_1 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_1 .

The next L_2 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_2 .

The next L_3 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_3 .

The remaining L_4 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_4 .

Finally the last 24 bits of the serial mother codeword shall be punctured as described in clause 11.1.2.

Each quadruple (L_1, L_2, L_3, L_4) associated to a quadruple (PI_1, PI_2, PI_3, PI_4) , defines a protection profile.

Five protection levels P ($P = 1, 2, 3, 4, 5$) are defined.

The permissible protection profiles are specified as a function of the audio bit rate and the protection level P in table 31 (see also table 6 of clause 6). To ensure a word length of a multiple of 64 bits at the output of the encoding process, a certain number of "zero value" padding bits shall be appended at the end of the punctured codeword for certain protection profiles, as specified in table 31.

The resulting convolutional codeword for a given logical frame is denoted $(b_i)_{i=0}^{M-1}$.

Table 31: Audio service component protection profiles

Audio bit rate (kbit/s)	P	L_1	L_2	L_3	L_4	PI_1	PI_2	PI_3	PI_4	number of padding bits
32	5	3	4	17	0	5	3	2	-	0
32	4	3	3	18	0	11	6	5	-	0
32	3	3	4	14	3	15	9	6	8	0
32	2	3	4	14	3	22	13	8	13	0
32	1	3	5	13	3	24	17	12	17	4
48	5	4	3	26	3	5	4	2	3	0
48	4	3	4	26	3	9	6	4	6	0
48	3	3	4	26	3	15	10	6	9	4
48	2	3	4	26	3	24	14	8	15	0
48	1	3	5	25	3	24	18	13	18	0
56	5	6	10	23	3	5	4	2	3	0
56	4	6	10	23	3	9	6	4	5	0
56	3	6	12	21	3	16	7	6	9	0
56	2	6	10	23	3	23	13	8	13	8
64	5	6	9	31	2	5	3	2	3	0
64	4	6	9	33	0	11	6	5	-	0
64	3	6	12	27	3	16	8	6	9	0
64	2	6	10	29	3	23	13	8	13	8
64	1	6	11	28	3	24	18	12	18	4
80	5	6	10	41	3	6	3	2	3	0
80	4	6	10	41	3	11	6	5	6	0
80	3	6	11	40	3	16	8	6	7	0
80	2	6	10	41	3	23	13	8	13	8
80	1	6	10	41	3	24	17	12	18	4
96	5	7	9	53	3	5	4	2	4	0
96	4	7	10	52	3	9	6	4	6	0
96	3	6	12	51	3	16	9	6	10	4
96	2	6	10	53	3	22	12	9	12	0
96	1	6	13	50	3	24	18	13	19	0
112	5	14	17	50	3	5	4	2	5	0
112	4	11	21	49	3	9	6	4	8	0
112	3	11	23	47	3	16	8	6	9	0
112	2	11	21	49	3	23	12	9	14	4
128	5	12	19	62	3	5	3	2	4	0
128	4	11	21	61	3	11	6	5	7	0
128	3	11	22	60	3	16	9	6	10	4
128	2	11	21	61	3	22	12	9	14	0
128	1	11	20	62	3	24	17	13	19	8
160	5	11	19	87	3	5	4	2	4	0
160	4	11	23	83	3	11	6	5	9	0
160	3	11	24	82	3	16	8	6	11	0
160	2	11	21	85	3	22	11	9	13	0
160	1	11	22	84	3	24	18	12	19	0
192	5	11	20	110	3	6	4	2	5	0
192	4	11	22	108	3	10	6	4	9	0
192	3	11	24	106	3	16	10	6	11	0
192	2	11	20	110	3	22	13	9	13	8
192	1	11	21	109	3	24	20	13	24	0
224	5	12	22	131	3	8	6	2	6	4
224	4	12	26	127	3	12	8	4	11	0
224	3	11	20	134	3	16	10	7	9	0
224	2	11	22	132	3	24	16	10	15	0
224	1	11	24	130	3	24	20	12	20	4
256	5	11	24	154	3	6	5	2	5	0
256	4	11	24	154	3	12	9	5	10	4
256	3	11	27	151	3	16	10	7	10	0
256	2	11	22	156	3	24	14	10	13	8

Audio bit rate (kbit/s)	P	L_1	L_2	L_3	L_4	PI_1	PI_2	PI_3	PI_4	number of padding bits
256	1	11	26	152	3	24	19	14	18	4
320	5	11	26	200	3	8	5	2	6	4
320	4	11	25	201	3	13	9	5	10	8
320	2	11	26	200	3	24	17	9	17	0
384	5	11	27	247	3	8	6	2	7	0
384	3	11	24	250	3	16	9	7	10	4
384	1	12	28	245	3	24	20	14	23	8

Table 32 gives the approximate value of the resulting average code rate as a function of the audio bit rate and the protection level P . In this table, the options denoted by X are not provided.

Table 32: Average code rate as a function of the audio bit rate and the protection level P

P	1	2	3	4	5
Audio bit rate (kbit/s)					
32	0,34	0,41	0,50	0,57	0,75
48	0,35	0,43	0,51	0,62	0,75
56	X	0,40	0,50	0,60	0,72
64	0,34	0,41	0,50	0,57	0,75
80	0,36	0,43	0,52	0,58	0,75
96	0,35	0,43	0,51	0,62	0,75
112	X	0,40	0,50	0,60	0,72
128	0,34	0,41	0,50	0,57	0,75
160	0,36	0,43	0,52	0,58	0,75
192	0,35	0,43	0,51	0,62	0,75
224	0,36	0,40	0,50	0,60	0,72
256	0,34	0,41	0,50	0,57	0,75
320	X	0,43	X	0,58	0,75
384	0,35	X	0,51	X	0,75

11.3.2 Equal Error Protection (EEP) coding

Each logical frame at the output of the energy dispersal scrambler (according to clause 10.3), corresponding to the processing of one or more data service components (Packet mode), or a single service component (Stream mode), consists of I -bit vector $(a_i)_{i=0}^{I-1}$, where I is a function of the bit rate.

NOTE: EEP profiles may be used for audio as well as data.

Each vector $(a_i)_{i=0}^{I-1}$ shall be processed as defined in clause 11.1.1. The first $4I$ bits of the serial mother codeword U are split into L consecutive blocks of 128 bits, as defined in clause 11.1.2.

The first L_1 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_1 .

The remaining L_2 blocks shall be punctured as defined in clause 11.1.2, according to the puncturing index PI_2 .

Finally, the last 24 bits of the serial mother codeword shall be punctured as defined in clause 11.1.2. No padding bits shall be added.

Each pair (L_1, L_2) associated to a pair (PI_1, PI_2) defines a protection profile.

The resulting convolutional codeword for a given logical frame is denoted $(b_i)_{i=0}^{M-1}$.

Bit rates in multiples of 8 kbit/s

Four protection levels are defined for bit rates in multiples of 8 kbit/s (see clauses 5.3.1 and 5.3.2). These four protection levels P ($P = 1, 2, 3, 4$), correspond to the code rates $1/4, 3/8, 1/2$ and $3/4$ respectively.

The value of L for each possible bit rate shall comply with table 33.

Table 33: Correspondence between the possible bit rates and the parameters I and L

Data bit rate (kbit/s)	I	L
8	192	6
:	:	:
:	:	:
8n	192n	6n
:	:	:
:	:	:
1 728	41 472	1 296

The permissible protection profiles (set A) are specified as a function of the bit rate, and the protection level P , in table 34.

Table 34: Equal error protection profiles (set A)

Data bit rate (kbit/s)	P	L_1	L_2	PI_1	PI_2
8n	4-A	4n-3	2n+3	3	2
8n	3-A	6n-3	3	8	7
8	2-A	5	1	13	12
8n (n>1)		2n-3	4n+3	14	13
8n	1-A	6n-3	3	24	23

Bit rates in multiples of 32 kbit/s

Four protection levels are defined for bit rates in multiples of 32 kbit/s (see clauses 5.3.1. and 5.3.2.). These four protection levels P ($P = 1, 2, 3, 4$), correspond to the code rates 4/9, 4/7, 2/3 and 4/5 respectively.

The value of L for each possible bit rate shall comply with table 35.

Table 35: Correspondence between the possible bit rates and the parameters I and L

Data bit rate (kbit/s)	I	L
32	768	24
:	:	:
:	:	:
32n	768n	24n
:	:	:
:	:	:
1 824	43 776	1 368

The permissible protection profiles (set B) are specified as a function of the bit rate, and the protection level P , in table 36.

Table 36: Equal error protection profiles (set B)

Data bit rate (kbit/s)	P	L_1	L_2	PI_1	PI_2
32n	4-B	24n-3	3	2	1
32n	3-B	24n-3	3	4	3
32n	2-B	24n-3	3	6	5
32n	1-B	24n-3	3	10	9

11.3.3 Future error protection coding

There is provision for new error protection coding schemes, as indicated in clause 6.2. This may be required for new applications different from those defined in clauses 7 and 8. However, the encoding procedures specified in clause 11.1 shall apply.

12 Time interleaving

Time interleaving shall be applied to the output of each convolutional encoder for all sub-channels of the Main Service Channel (MSC). It shall not be applied to the FIC.

The output of each individual convolutional encoder is a sequence of convolutional codewords denoted $(\mathbf{B}_r)_{r=-\infty}^{\infty}$ where r is defined as the time index ranging from $-\infty$ to $+\infty$, whose value taken modulo 5 000 ($\text{mod}(r, 5\,000)$) is equal to the logical frame count of the corresponding logical frame. The time index is introduced for the purpose of describing system properties over several logical frames independently of the absolute time. It is notionally related to the logical frame count in such a way that they are aligned at r equals 0.

The convolutional codeword \mathbf{B}_r is denoted as a vector:

$$\mathbf{B}_r = (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,M_r-1})$$

of length M_r consisting of bits b_{r,i_r} .

The length M_r of these vectors depends on the index r , because it may change from one logical frame to the next, if a multiplex re-configuration occurs.

However, due to the limitation on the minimum time between two successive multiplex re-configurations (see clause 6), the value of M_r is not allowed to change more than once during a period of 250 logical frames.

The output of the interleaver is denoted as a sequence $(\mathbf{C}_r)_{r=-\infty}^{\infty}$ of vectors,

$$\mathbf{C}_r = (c_{r,0}, c_{r,1}, \dots, c_{r,i_r}, \dots, c_{r,N_r-1})$$

of length N_r consisting of bits c_{r,i_r} . The sequence of vectors constitutes the content of a sub-channel.

As long as the multiplex configuration remains stable, the length of the vector \mathbf{C}_r shall be equal to the length of the vector \mathbf{B}_r , i.e. $N_r = M_r$. During a time period of 15 logical frames after a multiplex re-configuration event, the length N_r may be larger than M_r for some sub-channels. The relation between N_r and M_r is defined later in this clause.

The time interleaving shall be performed according to the following relation:

$$c_{r,i_r} = \begin{cases} b_{r',i_r} & \text{if } i_r \leq M_{r'} - 1 \\ 0 & \text{if not} \end{cases}$$

for $i_r = 0, 1, 2, \dots, N_r - 1$ and all integers r .

The relationship between the indices r' , r and i_r is specified in table 37, where r' is given as a function of r for each of the possible values of i_r modulo 16.

Table 37: Relationship between the indices r' , r and i_r

$R(i_r/16)$	$r'(r, i_r)$
0	r
1	$r-8$
2	$r-4$
3	$r-12$
4	$r-2$
5	$r-10$
6	$r-6$
7	$r-14$
8	$r-1$
9	$r-9$
10	$r-5$
11	$r-13$
12	$r-3$
13	$r-11$
14	$r-7$
15	$r-15$

The following shall apply for the relationship between the values of M_r and N_r .

- a) If M_r has been constant over the last 16 frames, i.e.:

$$M_r = M_{r-1} = \dots = M_{r-15};$$

then

$$N_r = M_r.$$

- b) If M_r has increased during this period, i.e.:

$$M_r > M_{r-15};$$

then

$$N_r = M_r.$$

- c) If M_r has decreased over the last 16 frames, i.e.:

$$M_r < M_{r-15};$$

then

$$N_r = M_{r-15}.$$

NOTE: There is a one-to-one correspondence between M_r and N_r which may be expressed by the following two equivalent equations:

$$N_r = \max(M_r, M_{r-15});$$

or equivalently

$$M_r = \min(N_r, N_{r+15}).$$

The time interleaving rule is illustrated by the three following examples:

EXAMPLE 1: Time interleaving of a data service component with a bit rate of 8 kbit/s protected by protection level 4.

It is supposed that no multiplex re-configuration occurs.

The convolutional codeword \mathbf{B}_r is:

$$\mathbf{B}_r = (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,255}).$$

In this example, $M_r = N_r = 256$ for all values of r .

Figure 73 illustrates the time interleaving rule.

EXAMPLE 2: Time interleaving of a data service component with a bit rate of 8 kbit/s protected by protection level 4, and re-configured to a data service component with a bit rate of 8 kbit/s protected by protection level 3.

The convolutional codeword \mathbf{B}_r is:

$$\mathbf{B}_r = \begin{cases} (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,255}) & \text{for } r \leq r_0 - 1 \\ (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,383}) & \text{for } r \geq r_0 \end{cases}$$

$$\text{In this example, } M_r = \begin{cases} 256 & \text{for } r \leq r_0 - 1 \\ 384 & \text{for } r \geq r_0 \end{cases}$$

The value of N_r is given by:

$$N_r = \begin{cases} 256 & \text{for } r \leq r_0 - 1 \\ 384 & \text{for } r \geq r_0 \end{cases}$$

Figure 74 illustrates the time interleaving rule.

EXAMPLE 3: Time interleaving of a data service component with a bit rate of 8 kbit/s protected by protection level 3, and re-configured to a data service component with a bit rate of 8 kbit/s protected by protection level 4.

The convolutional codeword \mathbf{B}_r is:

$$\mathbf{B}_r = \begin{cases} (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,383}) & \text{for } r \leq r_0 - 1 \\ (b_{r,0}, b_{r,1}, \dots, b_{r,i_r}, \dots, b_{r,255}) & \text{for } r \geq r_0 \end{cases}$$

$$\text{In this example, } M_r = \begin{cases} 384 & \text{for } r \leq r_0 - 1 \\ 256 & \text{for } r \geq r_0 \end{cases}$$

The value of N_r is given by:

$$N_r = \begin{cases} 384 & \text{for } r \leq r_0 + 14 \\ 256 & \text{for } r \geq r_0 + 15 \end{cases}$$

Figure 75 illustrates the time interleaving rule.

Time interleaver input		Time interleaver output															time →
r-1	r	r	r+1	r+2	r+3	r+4	r+5	r+6	r+7	r+8	r+9	r+10	r+11	r+12	r+13	r+14	r+15
a _{r-1,0}	a _{r,0}	a _{r,0}	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,1}	a _{r,1}	a _{r-8,1}	a _{r-7,1}	a _{r-6,1}	a _{r-5,1}	a _{r-4,1}	a _{r-3,1}	a _{r-2,1}	a _{r-1,1}	a _{r,1}	....	....	....	....	....	....	....
a _{r-1,2}	a _{r,2}	a _{r-4,2}	a _{r-3,2}	a _{r-2,2}	a _{r-1,2}	a _{r,2}	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,3}	a _{r,3}	a _{r-12,3}	a _{r-11,3}	a _{r-10,3}	a _{r-9,3}	a _{r-8,3}	a _{r-7,3}	a _{r-6,3}	a _{r-5,3}	a _{r-4,3}	a _{r-3,3}	a _{r-2,3}	a _{r-1,3}	a _{r,3}	....	....	....
a _{r-1,4}	a _{r,4}	a _{r-2,4}	a _{r-1,4}	a _{r,4}	....	....	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,5}	a _{r,5}	a _{r-10,5}	a _{r-9,5}	a _{r-8,5}	a _{r-7,5}	a _{r-6,5}	a _{r-5,5}	a _{r-4,5}	a _{r-3,5}	a _{r-2,5}	a _{r-1,5}	a _{r,5}	....	....	....	....	....
a _{r-1,6}	a _{r,6}	a _{r-6,6}	a _{r-5,6}	a _{r-4,6}	a _{r-3,6}	a _{r-2,6}	a _{r-1,6}	a _{r,6}	....	....	....	....	....	....	....	....	....
a _{r-1,7}	a _{r,7}	a _{r-14,7}	a _{r-13,7}	a _{r-12,7}	a _{r-11,7}	a _{r-10,7}	a _{r-9,7}	a _{r-8,7}	a _{r-7,7}	a _{r-6,7}	a _{r-5,7}	a _{r-4,7}	a _{r-3,7}	a _{r-2,7}	a _{r-1,7}	a _{r,7}	....
a _{r-1,8}	a _{r,8}	a _{r-1,8}	a _{r,8}	....	....	....	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,9}	a _{r,9}	a _{r-9,9}	a _{r-8,9}	a _{r-7,9}	a _{r-6,9}	a _{r-5,9}	a _{r-4,9}	a _{r-3,9}	a _{r-2,9}	a _{r-1,9}	a _{r,9}	....	....	....	....	....	....
a _{r-1,10}	a _{r,10}	a _{r-5,10}	a _{r-4,10}	a _{r-3,10}	a _{r-2,10}	a _{r-1,10}	a _{r,10}	....	....	....	....	....	....	....	....	....	....
a _{r-1,11}	a _{r,11}	a _{r-13,11}	a _{r-12,11}	a _{r-11,11}	a _{r-10,11}	a _{r-9,11}	a _{r-8,11}	a _{r-7,11}	a _{r-6,11}	a _{r-5,11}	a _{r-4,11}	a _{r-3,11}	a _{r-2,11}	a _{r-1,11}	a _{r,11}	....	....
a _{r-1,12}	a _{r,12}	a _{r-3,12}	a _{r-2,12}	a _{r-1,12}	a _{r,12}	....	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,13}	a _{r,13}	a _{r-11,13}	a _{r-10,13}	a _{r-9,13}	a _{r-8,13}	a _{r-7,13}	a _{r-6,13}	a _{r-5,13}	a _{r-4,13}	a _{r-3,13}	a _{r-2,13}	a _{r-1,13}	a _{r,13}	....	....	....	....
a _{r-1,14}	a _{r,14}	a _{r-7,14}	a _{r-6,14}	a _{r-5,14}	a _{r-4,14}	a _{r-3,14}	a _{r-2,14}	a _{r-1,14}	a _{r,14}	....	....	....	....	....	....	....	....
a _{r-1,15}	a _{r,15}	a _{r-15,15}	a _{r-14,15}	a _{r-13,15}	a _{r-12,15}	a _{r-11,15}	a _{r-10,15}	a _{r-9,15}	a _{r-8,15}	a _{r-7,15}	a _{r-6,15}	a _{r-5,15}	a _{r-4,15}	a _{r-3,15}	a _{r-2,15}	a _{r-1,15}	a _{r,15}
a _{r-1,16}	a _{r,16}	a _{r,16}	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
a _{r-1,17}	a _{r,17}	a _{r-8,17}	a _{r-7,17}	a _{r-6,17}	a _{r-5,17}	a _{r-4,17}	a _{r-3,17}	a _{r-2,17}	a _{r-1,17}	a _{r,17}	....	....	....	....	....	....	....
a _{r-1,18}	a _{r,18}	a _{r-4,18}	a _{r-3,18}	a _{r-2,18}	a _{r-1,18}	a _{r,18}	....	....	....	....	....	....	....	....	....	....	....
....
....
....
a _{r-1,255}	a _{r,255}	a _{r-15,255}	a _{r-14,255}	a _{r-13,255}	a _{r-12,255}	a _{r-11,255}	a _{r-10,255}	a _{r-9,255}	a _{r-8,255}	a _{r-7,255}	a _{r-6,255}	a _{r-5,255}	a _{r-4,255}	a _{r-3,255}	a _{r-2,255}	a _{r-1,255}	a _{r,255}

Figure 73: Illustration of time interleaving for example 1

Time interleaver input																time →			
r_{0-3}	r_{0-2}	r_{0-1}	r_0	r_{0+1}	r_{0+2}	r_{0+3}	r_{0+4}	r_{0+5}	r_{0+6}	r_{0+7}	r_{0+8}	r_{0+9}	r_{0+10}	r_{0+11}	r_{0+12}	r_{0+13}	r_{0+14}	r_{0+15}	r_{0+16}
....	$a_{r_{0-1},0}$	$a_{r_0,0}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	$a_{r_{0-1},1}$	$a_{r_0,1}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....
....	$a_{r_{0-1},255}$	$a_{r_0,255}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
		
			$a_{r_0,383}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Time interleaver output																			
....	$a_{r_{0-1},0}$	$a_{r_0,0}$	....	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+14},0}$	$a_{r_{0+15},0}$	....
....	$a_{r_{0-9},1}$	$a_{r_{0-8},1}$	....	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+6},1}$	$a_{r_{0+7},1}$	....
....
....	$a_{r_{0-16},255}$	$a_{r_{0-15},255}$	....	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0-1},255}$	$a_{r_0,255}$	....
			$a_{r_0,256}$	$a_{r_{0+1},256}$	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+14},256}$	$a_{r_{0+15},256}$	....
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+6},257}$	$a_{r_{0+7},257}$	....
		
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_0,263}$	$a_{r_{0+1},263}$	....
			0	$a_{r_0,264}$	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+13},264}$	$a_{r_{0+14},264}$	....
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+5},265}$	$a_{r_{0+6},265}$	....
		
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	0	$a_{r_0,271}$	....
			$a_{r_0,272}$	$a_{r_{0+1},272}$	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+14},272}$	$a_{r_{0+15},272}$	....
		
			0	$a_{r_0,376}$	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+13},376}$	$a_{r_{0+14},376}$	....
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+5},377}$	$a_{r_{0+6},377}$	....
		
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	$a_{r_{0+7},382}$	$a_{r_{0+8},382}$	....
			0	0	....	....	....	....	....	....	....	....	....	....	....	....	0	$a_{r_0,383}$	....

Figure 74: Illustration of time interleaving for example 2

13 Common Interleaved Frame

This clause specifies the bit structure of the Common Interleaved Frame (CIF). Each vector C_r at the output of a time interleaver (specified in clause 12) contains a multiple of 64 bits, and therefore, every sub-channel occupies an integral number of CUs in the CIF.

Using the notation of clause 12, the required number of CUs for a sub-channel during the CIF of time index r , is equal to $N_r/64$.

The vectors C_r for the various sub-channels shall be multiplexed in such a way that every sub-channel shall occupy an integral number of consecutive CUs.

The address of the CU assigned to the first bit of a vector C_r is called the start address.

The CIF bits shall be assigned consecutively so that the first bit of each vector C_r at the output of a time interleaver shall be assigned to the first bit of the CU of start address, and the last bit of each vector C_r shall be assigned to the last bit of the last CU assigned to that sub-channel.

If the set of sub-channels do not fill the whole CIF, all unassigned CUs shall be filled with padding bits. The value of the padding bits shall be defined as follows:

If the $(i+1)^{\text{th}}$ bit of the CIF belongs to a CU containing padding bits, it shall take the value of the $(i+1)^{\text{th}}$ bit of the PRBS defined in clause 10.

These rules are illustrated in figure 76.

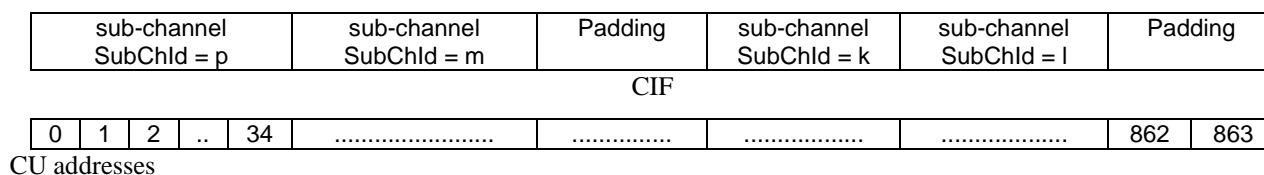


Figure 76: Example of a CIF structure

The $(i+1)^{\text{th}}$ bit of the CIF of index r shall be denoted by $d_{r,i}$ ($i=0, 1, 2, \dots, 55\ 295$).

The index r taken modulo 5 000 ($\text{mod}(r, 5\ 000)$) is equal to the CIF count defined in clause 5.3.

The structure of the CIF is signalled by the MCI, as defined in clause 6.2.

14 DAB transmission signal

14.1 General principles

The transmitted signal is built up around a transmission frame structure corresponding to the juxtaposition in time of the synchronization channel, the FIC and the MSC (see also clause 5.1).

The transmission frame duration is denoted by T_F .

The structure of the transmission frame is shown in figure 77.

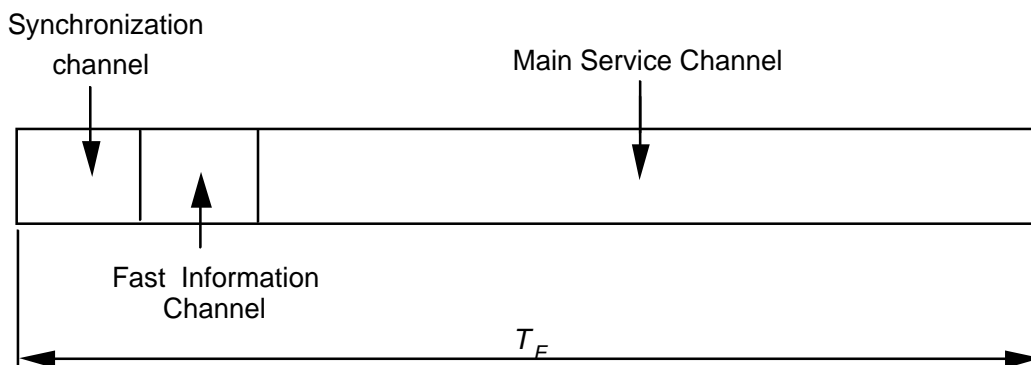


Figure 77: Transmission frame structure

Four transmission modes are defined, each having its particular set of parameters. The use of these transmission modes depends on the network configuration and operating frequencies, as defined in clause 15.

Each transmission frame is divided into a sequence of OFDM symbols, each symbol consisting of a number of carriers. The DAB transmission signal is defined as the sum of two signals; the main signal $s(t)$ and an optional signal $s_{TII}(t)$ as illustrated in figure 1. Clause 14.2 define the main signal. The clauses 14.3 to 14.7 specify the content of the synchronization channel as well as the processing applied to the convolutionally encoded FIBs and the CIFs in order to generate the main signal $s(t)$. Clause 14.8 specifies the generation of the signal $s_{TII}(t)$.

14.2 Structure of the main signal

Each transmission frame shall consist of consecutive OFDM symbols. The number of OFDM symbols in a transmission frame is dependent on the transmission mode. The synchronization channel in any transmission mode shall occupy the first two OFDM symbols of each transmission frame.

The first OFDM symbol of the transmission frame shall be the Null symbol of duration T_{NULL} . The remaining part of the transmission frame shall be a juxtaposition of OFDM symbols of duration T_S .

Each of these OFDM symbols shall consist of a set of equally-spaced carriers, with a carrier spacing equal to $1/T_U$. The main signal $s(t)$ shall be defined using the following formula:

$$s(t) = \text{Re} \left\{ e^{2j\pi f_c t} \sum_{m=-\infty}^{+\infty} \sum_{l=0}^L \sum_{k=-K/2}^{K/2} z_{m,l,k} \cdot g_{k,l}(t - mT_F - T_{NULL} - (l-1)T_S) \right\}$$

with,

$$g_{k,l}(t) = \begin{cases} 0 & \text{for } l = 0 \\ e^{2j\pi k(t-\Delta)/T_U} \cdot \text{Rect}(t/T_S) & \text{for } l = 1, 2, \dots, L \end{cases}$$

and $T_S = T_U + \Delta$.

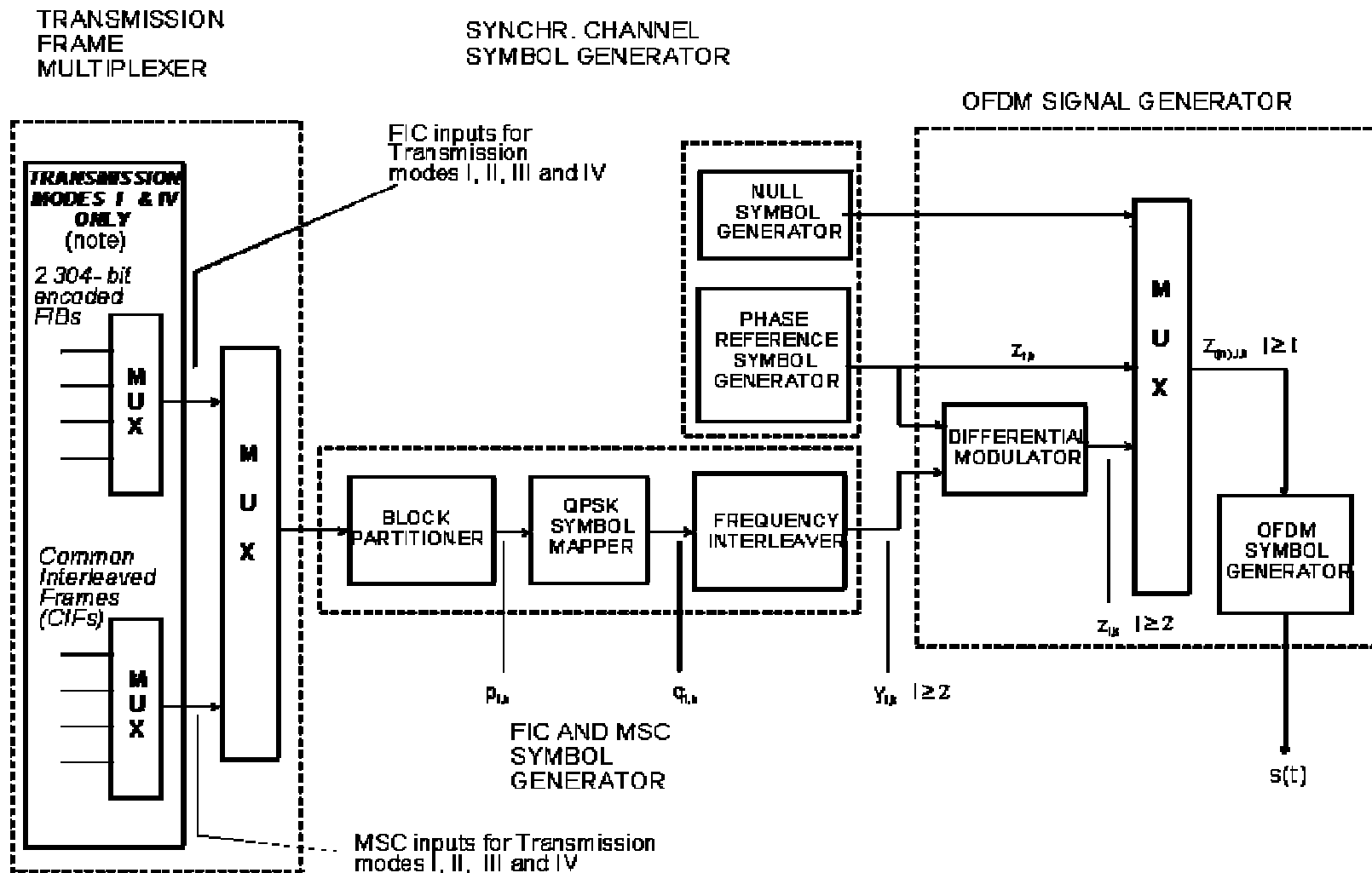
The various parameters and variables are defined as follows:

- L is the number of OFDM symbols per transmission frame (the Null symbol being excluded);
- K is the number of transmitted carriers;
- T_F is the transmission frame duration;
- T_{NULL} is the Null symbol duration;
- T_S is the duration of OFDM symbols of indices $l = 1, 2, 3, \dots, L$;
- T_U is the inverse of the carrier spacing;
- Δ is the duration of the time interval called guard interval;
- $z_{m, l, k}$ is the complex D-QPSK symbol associated to carrier k of OFDM symbol l during transmission frame m . Its values are defined in the following clauses. For $k = 0$, $z_{m, l, k} = 0$, so that the central carrier is not transmitted;
- f_c is the central frequency of the signal. The possible values of f_c are given in clause 15.

These parameters are specified in table 38 for transmission modes I, II, III and IV. The values of the various time-related parameters are given in multiples of the elementary period $T = 1/2\ 048\ 000$ seconds, and approximately in milliseconds or microseconds.

Table 38: Definition of the parameters for transmission modes I, II, III and IV

Parameter	Transmission mode I	Transmission mode II	Transmission mode III	Transmission mode IV
L	76	76	153	76
K	1536	384	192	768
T_F	196 608 T 96 ms	49 152 T 24 ms	49 152 T 24 ms	98 304 T 48 ms
T_{NULL}	2 656 T ~1,297 ms	664 T ~324 μ s	345 T ~168 μ s	1 328 T ~648 μ s
T_S	2 552 T ~1,246 ms	638 T ~312 μ s	319 T ~156 μ s	1 276 T ~623 μ s
T_U	2 048 T 1 ms	512 T 250 μ s	256 T 125 μ s	1 024 T 500 μ s
Δ	504 T ~246 μ s	126 T ~62 μ s	63 T ~31 μ s	252 T ~123 μ s



NOTE 1: In transmission mode I, the 4 inputs of each MUX are used.

NOTE 2: In transmission mode IV, only 2 inputs of each MUX are used.

Figure 78: Conceptual block diagram of the generation of the main signal

Clauses 14.4 to 14.7 describe the generation of the complex D-QPSK symbols $z_{m, l, k}$ constituting a transmission frame. Since the same processing is applied for every transmission frame, the index m will be suppressed when appropriate.

The generation of the main signal $s(t)$ is described in the conceptual block diagram of figure 78.

14.3 Synchronization channel

This clause specifies the characteristics of the synchronization channel which consists of the first two OFDM symbols of each transmission frame. This channel may also be used for carrying optional Transmitter Identification Information (TII) (see clause 14.8), by adding to the null symbol defined in clause 14.2, the TII signal.

14.3.1 Null symbol

As previously described, the first OFDM symbol of the transmission frame is the null symbol. During the time interval $[0, T_{NULL}]$, the main signal $s(t)$ shall be equal to 0.

14.3.2 Phase reference symbol

The second OFDM symbol of the transmission frame is the phase reference symbol. It constitutes the reference for the differential modulation for the next OFDM symbol. The phase reference symbol is defined by the values of $z_{l, k}$ for $l = 1$:

$$z_{1,k} = \begin{cases} e^{j\varphi_k} & \text{for } -\frac{K}{2} \leq k < 0 \text{ and } 0 < k \leq \frac{K}{2} \\ 0 & \text{for } k = 0 \end{cases}$$

The values of φ_k shall be obtained from the following formula:

$$\varphi_k = \frac{\pi}{2} (h_{i, k-k'} + n)$$

The indices i, k' and the parameter n are specified as functions of the carrier index k for the four transmission modes in tables 44 to 47.

The values of the parameter $h_{i, j}$ as a function of its indices i and j , are specified in table 43.

Table 39: Relation between the indices i , k' and n and the carrier index k for transmission mode I

k in the range of min		k in the range of max		k'	i	n
-768	-737	-768	0	1		
-736	-705	-736	1	2		
-704	-673	-704	2	0		
-672	-641	-672	3	1		
-640	-609	-640	0	3		
-608	-577	-608	1	2		
-576	-545	-576	2	2		
-544	-513	-544	3	3		
-512	-481	-512	0	2		
-480	-449	-480	1	1		
-448	-417	-448	2	2		
-416	-385	-416	3	3		
-384	-353	-384	0	1		
-352	-321	-352	1	2		
-320	-289	-320	2	3		
-288	-257	-288	3	3		
-256	-225	-256	0	2		
-224	-193	-224	1	2		
-192	-161	-192	2	2		
-160	-129	-160	3	1		
-128	-97	-128	0	1		
-96	-65	-96	1	3		
-64	-33	-64	2	1		
-32	-1	-32	3	2		

k in the range of min		k in the range of max		k'	i	n
1	32	1	0	3		
33	64	33	3	1		
65	96	65	2	1		
97	128	97	1	1		
129	160	129	0	2		
161	192	161	3	2		
193	224	193	2	1		
225	256	225	1	0		
257	288	257	0	2		
289	320	289	3	2		
321	352	321	2	3		
353	384	353	1	3		
385	416	385	0	0		
417	448	417	3	2		
449	480	449	2	1		
481	512	481	1	3		
513	544	513	0	3		
545	576	545	3	3		
577	608	577	2	3		
609	640	609	1	0		
641	672	641	0	3		
673	704	673	3	0		
705	736	705	2	1		
737	768	737	1	1		

Table 40: Relation between the indices i , k' and n and the carrier index k for transmission mode II

k in the range of min		k in the range of max		k'	i	n
-192	-161	-192	0	2		
-160	-129	-160	1	3		
-128	-97	-128	2	2		
-96	-65	-96	3	2		
-64	-33	-64	0	1		
-32	-1	-32	1	2		

k in the range of min		k in the range of max		k'	i	n
1	32	1	2	0		
33	64	33	1	2		
65	96	65	0	2		
97	128	97	3	1		
129	160	129	2	0		
161	192	161	1	3		

Table 41: Relation between the indices i , k' and n and the carrier index k for transmission mode III

k in the range of min		k in the range of max		k'	i	n
-96	-65	-96	0	2		
-64	-33	-64	1	3		
-32	-1	-32	2	0		

k in the range of min		k in the range of max		k'	i	n
1	32	1	3	2		
33	64	33	2	2		
65	96	65	1	2		

Table 42: Relation between the indices i , k' and n and the carrier index k for transmission mode IV

k in the range of min		k in the range of max		k'	i	n
-384	-353	-384	-353	-384	0	0
-352	-321	-352	-321	-352	1	1
-320	-289	-320	-289	-320	2	1
-288	-257	-288	-257	-288	3	2
-256	-225	-256	-225	-256	0	2
-224	-193	-224	-193	-224	1	2
-192	-161	-192	-161	-192	2	0
-160	-129	-160	-129	-160	3	3
-128	-97	-128	-97	-128	0	3
-96	-65	-96	-65	-96	1	1
-64	-33	-64	-33	-64	2	3
-32	-1	-32	-1	-32	3	2

k in the range of min		k in the range of max		k'	i	n
1	32	1	32	1	0	0
33	64	33	64	33	3	1
65	96	65	96	65	2	0
97	128	97	128	97	1	2
129	160	129	160	129	0	0
161	192	161	192	161	3	1
193	224	193	224	193	2	2
225	256	225	256	225	1	2
257	288	257	288	257	0	2
289	320	289	320	289	3	1
321	352	321	352	321	2	3
353	384	353	384	353	1	0

Table 43: Time-Frequency-Phase parameter h values

j	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$h_{0,j}$	0	2	0	0	0	0	1	1	2	0	0	0	2	2	1	1
$h_{1,j}$	0	3	2	3	0	1	3	0	2	1	2	3	2	3	3	0
$h_{2,j}$	0	0	0	2	0	2	1	3	2	2	0	2	2	0	1	3
$h_{3,j}$	0	1	2	1	0	3	3	2	2	3	2	1	2	1	3	2

j	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
$h_{0,j}$	0	2	0	0	0	0	1	1	2	0	0	0	2	2	1	1
$h_{1,j}$	0	3	2	3	0	1	3	0	2	1	2	3	2	3	3	0
$h_{2,j}$	0	0	0	2	0	2	1	3	2	2	0	2	2	0	1	3
$h_{3,j}$	0	1	2	1	0	3	3	2	2	3	2	1	2	1	3	2

14.3.3 Time reference

The synchronization channel shall serve as the reference for the time information carried in the FIC (see clause 8.1.3). The time information carried in the FIC shall be taken to be the time of transmission of the start of the null symbol in the transmission frame carrying the time information.

14.4 Block partitioning and association of blocks to OFDM symbols

This clause defines the process applied to the sequence of convolutionally encoded FIBs and to the sequence of CIFs, to constitute the blocks of data which will be associated to OFDM symbols. This process is transmission mode dependent.

14.4.1 Block partitioning and association of blocks to OFDM symbols in the Fast Information Channel

14.4.1.1 Transmission mode I

In transmission mode I, four groups of convolutionally encoded FIBs shall be transmitted within each transmission frame, as indicated in clause 5.1.

Four convolutional codewords, defined in clause 11.2.1 corresponding to four consecutive groups of FIBs shall be multiplexed to form a vector, which shall then be divided into three blocks to be transmitted on three OFDM symbols.

The bits b_i of the convolutional codeword $(b_i)_{i=0}^{2303}$ defined in clause 11.2.1 will, in this clause, be indexed by the time index r , and will be denoted $b_{r,i}$. The index r is defined in such a way that its value modulo 5000 ($\text{mod}(r, 5000)$) is equal to the CIF count defined in clause 5.3. This relationship follows from the association of FIBs to CIFs, see clause 5.1.

The multiplexing of four consecutive convolutional codewords into one vector \mathbf{B}' is defined by the following relation:

$$\begin{aligned} b'_{i'} &= b_{r,i} \\ \text{and} \\ i' &= i + 2304 \cdot \text{mod}(r,4) \text{ for } i = 0,1,2,\dots,2303 \text{ and for any value of } r. \end{aligned}$$

where:

$b'_{i'}$ denotes the $(i'+1)^{\text{th}}$ bit of the vector \mathbf{B}' ;

$b_{r,i}$ denotes the $(i+1)^{\text{th}}$ bit of the $(r+1)^{\text{th}}$ convolutional codeword.

This means that the arrangement of convolutionally encoded FIBs in a transmission frame shall be such that convolutionally encoded FIBs of CIF counts 0, 1, 2 and 3 are transmitted in the same transmission frame, those of CIF counts 4, 5, 6 and 7 in the next transmission frame, and so on.

The vector $(b'_{i'})_{i'=0}^{9215}$ shall be divided into three consecutive blocks \mathbf{P}_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 2, 3, 4$ respectively.

Each block \mathbf{P}_l is a vector $(p_{l,n})_{n=0}^{3071}$, the bits $p_{l,n}$ being defined by:

$$\begin{aligned} p_{l,n} &= b'_i \\ \text{and} \\ l &= \text{Q}(i'/3072) + 2 & i' &= 0,1,2,\dots,9215 \\ n &= \text{R}(i'/3072) & i' &= 0,1,2,\dots,9215 \end{aligned}$$

The principle of this block partitioning is shown in figure 79, for $r = 0, 1, 2$ and 3.

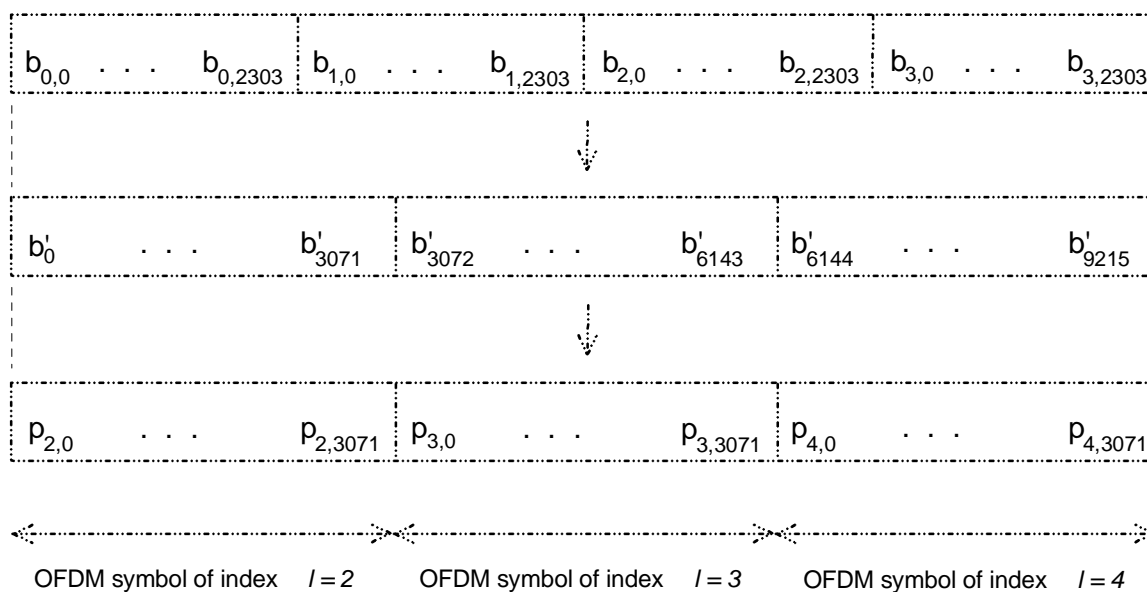


Figure 79: Block partitioning in the FIC for transmission mode I

14.4.1.2 Transmission mode II

The convolutional codeword defined in clause 11.2.1 shall be divided into three consecutive blocks P_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 2, 3, 4$ respectively.

Each block P_l is a vector $(p_{l,n})_{n=0}^{767}$, the bits $p_{l,n}$ being defined by:

$$\begin{aligned}
 p_{l,n} &= b_i \\
 \text{and} \\
 l &= Q(i/768) + 2 & i = 0, 1, 2, \dots, 2303 \\
 n &= R(i/768) & i = 0, 1, 2, \dots, 2303
 \end{aligned}$$

The principle of this block partitioning is shown in figure 80.

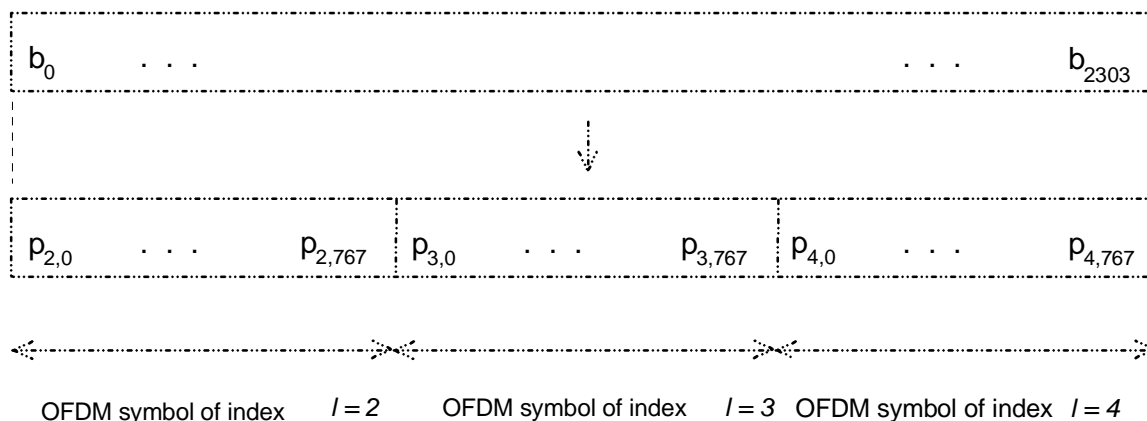


Figure 80: Block partitioning in the FIC for transmission mode II

14.4.1.3 Transmission mode III

The convolutional codeword $(b_i)_{i=0}^{3071}$ defined in clause 11.2.2 shall be divided into eight consecutive blocks P_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 2, 3, 4, \dots, 9$ respectively.

Each block P_l is a vector $(p_{l,n})_{n=0}^{383}$, the bits $p_{l,n}$ being defined by:

$$\begin{aligned}
 p_{l,n} &= b_i \\
 \text{and} \\
 l &= Q(i/384) + 2 & i = 0, 1, 2, \dots, 3071 \\
 n &= R(i/384) & i = 0, 1, 2, \dots, 3071
 \end{aligned}$$

The principle of this block partitioning is shown in figure 81.

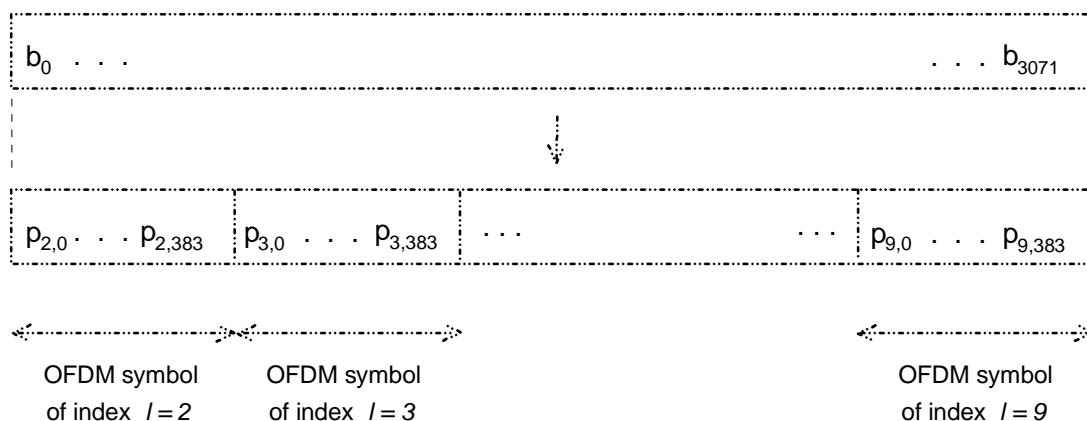


Figure 81: Block partitioning in the FIC for transmission mode III

14.4.1.4 Transmission mode IV

In transmission mode IV, two groups of convolutionally encoded FIBs shall be transmitted within each transmission frame, as indicated in clause 5.1.

Two convolutional codewords, defined in clause 11.2.1 corresponding to two consecutive groups of FIBs shall be multiplexed to form a vector, which shall then be divided into three blocks to be transmitted on three OFDM symbols.

The bits b_i of the convolutional codeword $(b_i)_{i=0}^{2303}$ defined in clause 11.2.1 will, in this clause, be indexed by the time index r , and will be denoted $b_{r,i}$. The index r is defined in such a way that its value modulo 5000 ($\text{mod}(r, 5000)$) is equal to the CIF count defined in clause 5.3. This relationship follows from the association of FIBs to CIFs, see clause 5.1.

The multiplexing of two consecutive convolutional codewords into one vector B' is defined by the following relation:

$$b'_{i'} = b_{r,i}$$

and

$$i' = i + 2304 \cdot \text{mod}(r, 2) \text{ for } i = 0, 1, 2, \dots, 2303 \text{ and for any value of } r.$$

where:

- $b'_{i'}$ denotes the $(i'+1)^{\text{th}}$ bit of the vector B' ;
- $b_{r,i}$ denotes the $(i+1)^{\text{th}}$ bit of the $(r+1)^{\text{th}}$ convolutional codeword.

This means that the arrangement of convolutionally encoded FIBs in a transmission frame shall be such that convolutionally encoded FIBs of CIF counts 0 and 1 are transmitted in the same transmission frame, those of CIF counts 2 and 3 in the next transmission frame, and so on.

The vector $(b'_{i'})_{i'=0}^{4607}$ shall be divided into three consecutive blocks P_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 2, 3, 4$ respectively.

Each block P_l is a vector $(p_{l,n})_{n=0}^{1535}$, the bits $p_{l,n}$ being defined by:

$$p_{l,n} = b'_{i'}$$

and

$$l = Q(i'/1536) + 2 \quad i' = 0, 1, 2, \dots, 4607$$

$$n = R(i'/1536) \quad i' = 0, 1, 2, \dots, 4607$$

The principle of this block partitioning is shown in figure 82, for $r = 0$ and 1.

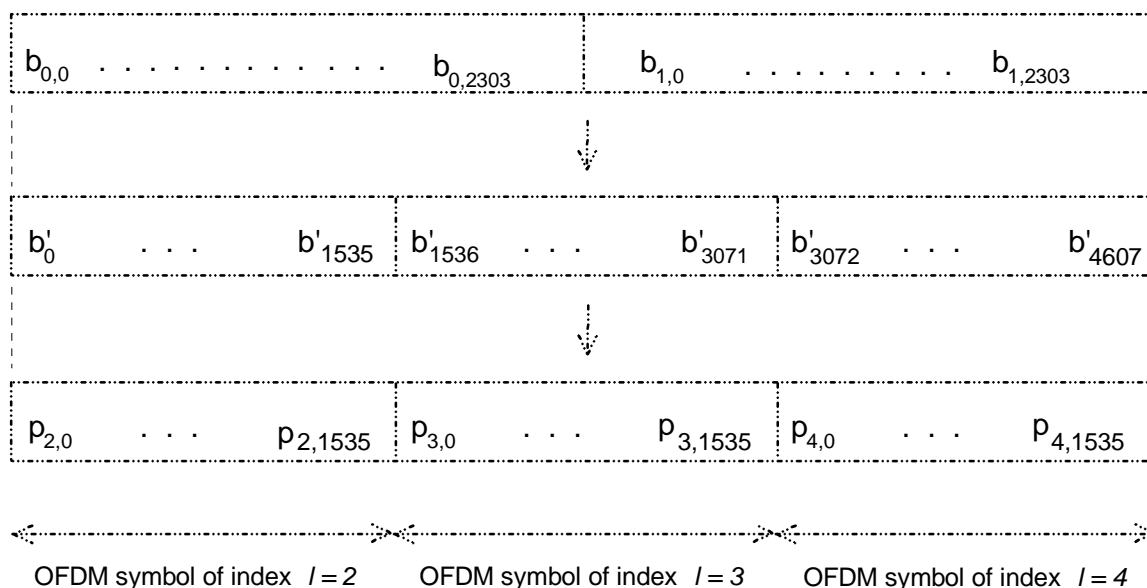


Figure 82: Block partitioning in the FIC for transmission mode IV

14.4.2 Block partitioning and association of blocks to OFDM symbols in the Main Service Channel

14.4.2.1 Transmission mode I

In transmission mode I, four CIFs shall be transmitted within each transmission frame as indicated in clause 5.1.

Four consecutive CIFs defined in clause 13 shall be multiplexed to form a vector, which shall then be divided into 72 blocks to be transmitted on 72 OFDM symbols.

The multiplexing of four consecutive CIFs into one vector \mathbf{D}' is defined by the following relation:

$$d'_{i'} = d_{r,i}$$

and

$$i' = i + 55296 \cdot \text{mod}(r,4) \text{ for } i = 0,1,2,\dots,55295 \text{ and for any value of } r.$$

where:

$d'_{i'}$ denotes the $(i'+1)^{\text{th}}$ bit of the vector \mathbf{D}' ;

$d_{r,i}$ denotes the $(i+1)^{\text{th}}$ bit of the $(r+1)^{\text{th}}$ CIF.

As defined in clause 13, the index r taken modulo 5000 ($\text{mod}(r, 5000)$) is equal to the CIF count defined in clause 5.3.

This means that the arrangement of CIFs in a transmission frame shall be such that CIFs of CIF count 0, 1, 2 and 3 are transmitted in the same transmission frame, those of CIF count 4, 5, 6 and 7 in the next transmission frame, and so on.

The vector $(d'_{i'})_{i'=0}^{221183}$ shall be divided into 72 consecutive blocks \mathbf{P}_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 5, 6, 7, \dots, 76$ respectively.

Each block \mathbf{P}_l is a vector $(p_{l,n})_{n=0}^{3071}$, the bits $p_{l,n}$ being defined by:

$$p_{l,n} = d'_{i'}$$

and

$$\begin{aligned} l &= Q(i'/3072) + 5 & i' &= 0, 1, 2, \dots, 221183 \\ n &= R(i'/3072) & i' &= 0, 1, 2, \dots, 221183 \end{aligned}$$

The principle of this block partitioning is shown in figure 83, for $r = 0, 1, 2$ and 3.

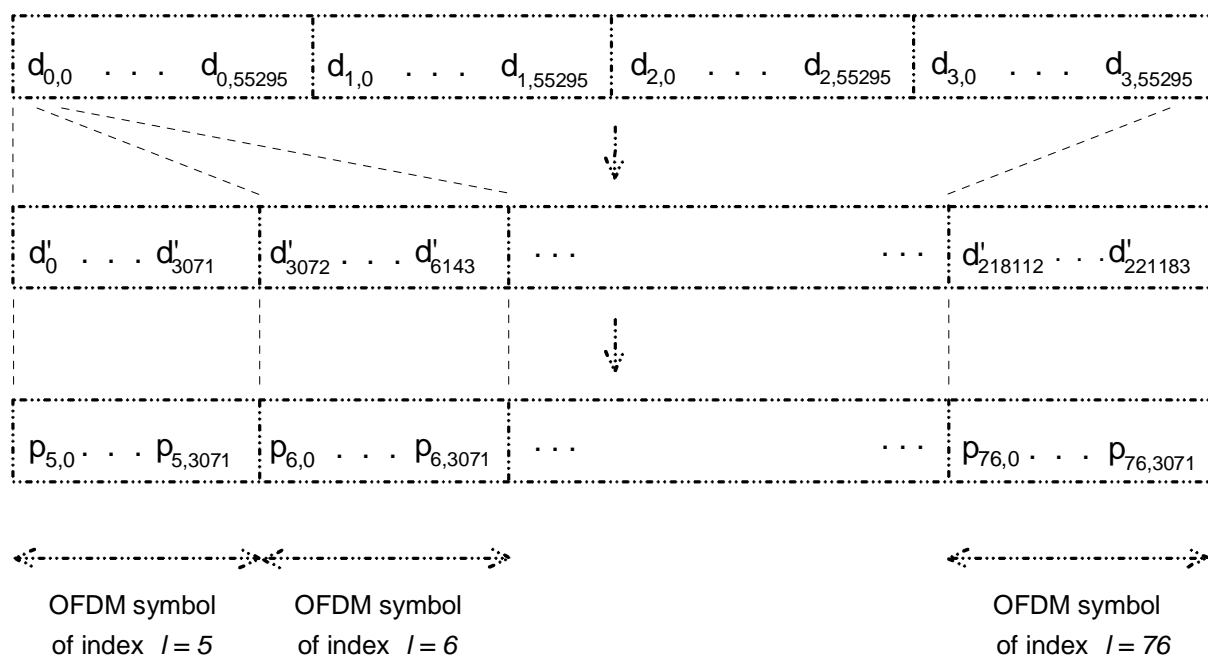


Figure 83: Block partitioning in the MSC for transmission mode I

14.4.2.2 Transmission mode II

The CIF constituted by the vector $(d_i)_{i=0}^{55295}$ defined in clause 13 shall be divided into 72 consecutive blocks \mathbf{P}_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 5, 6, 7, \dots, 76$ respectively.

The index r of $d_{r,i}$ is omitted here because the process is not depending on the value of r .

Each block \mathbf{P}_l is a vector $(p_{l,n})_{n=0}^{767}$, the bits $p_{l,n}$ being defined by:

$$p_{l,n} = d_i$$

and

$$\begin{aligned} l &= Q(i/768) + 5 & i &= 0, 1, 2, \dots, 55295 \\ n &= R(i/768) & i &= 0, 1, 2, \dots, 55295 \end{aligned}$$

The principle of this block partitioning is shown in figure 84.

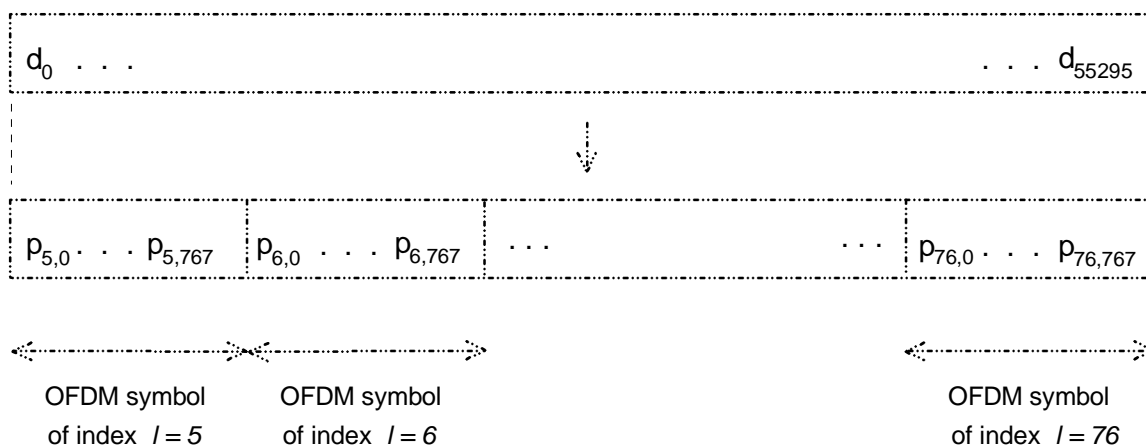


Figure 84: Block partitioning in the MSC for transmission mode II

14.4.2.3 Transmission mode III

The CIF constituted by the vector $(d_i)_{i=0}^{55295}$ defined in clause 13 shall be divided into 144 consecutive blocks P_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 10, 11, 12, \dots, 153$ respectively.

The index r of $d_{r,i}$ is omitted here because the process is not depending on the value of r .

Each block P_l is a vector $(p_{l,n})_{n=0}^{383}$, the bits $p_{l,n}$ being defined by:

$$\begin{aligned}
 p_{l,n} &= d_i \\
 \text{and} \\
 l &= Q(i/384) + 10 & i = 0, 1, 2, \dots, 55295 \\
 n &= R(i/384) & i = 0, 1, 2, \dots, 55295
 \end{aligned}$$

The principle of this block partitioning is shown in figure 85.

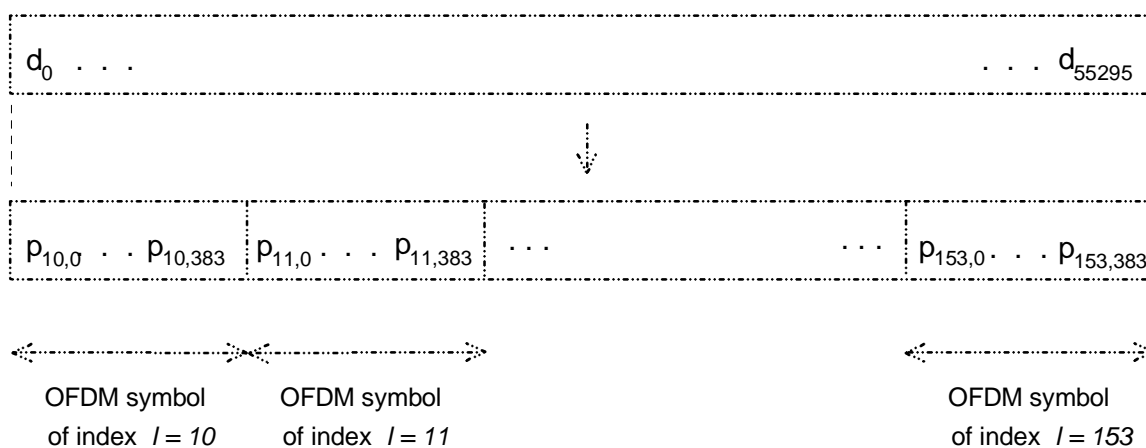


Figure 85: Block partitioning in the MSC for transmission mode III

14.4.2.4 Transmission mode IV

In transmission mode IV, two CIFs shall be transmitted within each transmission frame as indicated in clause 5.1.

Two consecutive CIFs defined in clause 13 shall be multiplexed to form a vector, which shall then be divided into 72 blocks to be transmitted on 72 OFDM symbols.

The multiplexing of two consecutive CIFs into one vector \mathbf{D}' is defined by the following relation:

$$d'_{i'} = d_{r,i}$$

and

$$i' = i + 55296 \cdot \text{mod}(r,2) \text{ for } i = 0,1,2,\dots,55295 \text{ and for any value of } r.$$

where:

- $d'_{i'}$ denotes the $(i'+1)^{\text{th}}$ bit of the vector \mathbf{D}' ;
- $d_{r,i}$ denotes the $(i+1)^{\text{th}}$ bit of the $(r+1)^{\text{th}}$ CIF.

As defined in clause 13, the index r taken modulo 5000 ($\text{mod}(r, 5000)$) is equal to the CIF count defined in clause 5.3.

This means that the arrangement of CIFs in a transmission frame shall be such that CIFs of CIF count 0 and 1 are transmitted in the same transmission frame, those of CIF count 2 and 3 in the next transmission frame, and so on.

The vector $(d'_{i'})_{i'=0}^{110591}$ shall be divided into 72 consecutive blocks \mathbf{P}_l , each block containing the bits to be transmitted in the OFDM symbol of index $l = 5, 6, 7, \dots, 76$ respectively.

Each block \mathbf{P}_l is a vector $(p_{l,n})_{n=0}^{1535}$, the bits $p_{l,n}$ being defined by:

$$p_{l,n} = d'_{i'}$$

and

$$l = \text{Q}(i'/1536) + 5 \quad i' = 0,1,2,\dots,110591$$

$$n = \text{R}(i'/1536) \quad i' = 0,1,2,\dots,110591$$

The principle of this block partitioning is shown in figure 86, for $r = 0$ and 1.

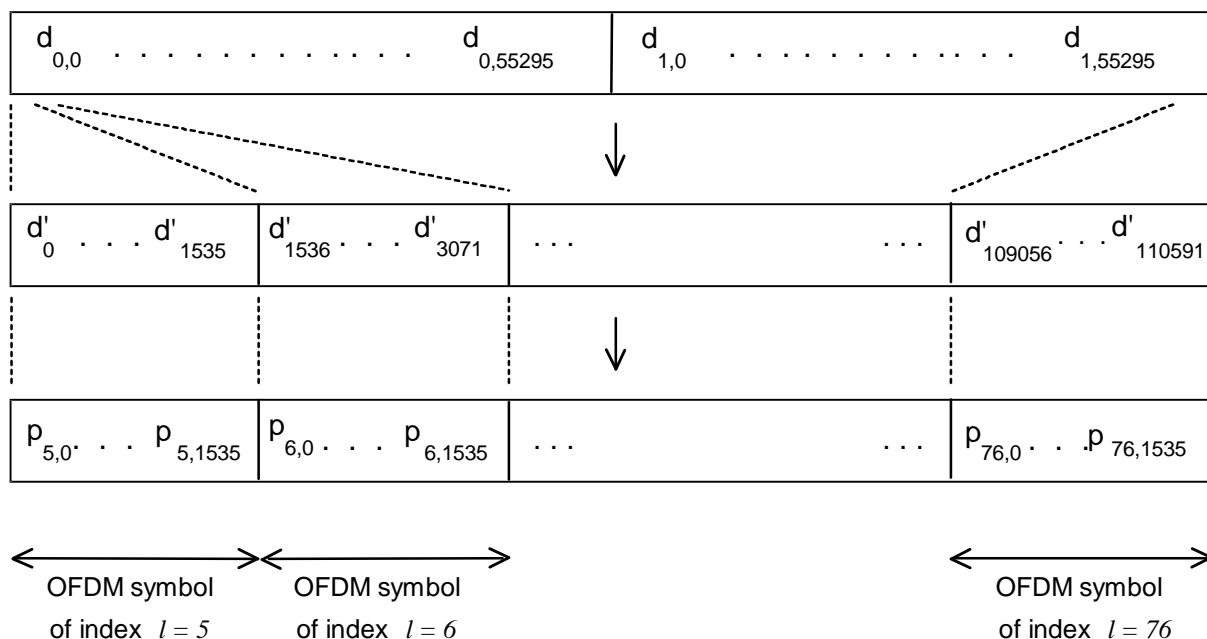


Figure 86: Block partitioning in the MSC for transmission mode IV

14.5 QPSK symbol mapper

For any of the OFDM symbols of index $l = 2, 3, 4, \dots, L$, the $2K$ -bit vector $(p_{l,n})_{n=0}^{2K-1}$, whose elements $p_{l,n}$ are defined in clauses 14.4.1 and 14.4.2, shall be mapped on the K complex QPSK symbols $q_{l,n}$ according to the following relation:

$$q_{l,n} = \frac{1}{\sqrt{2}} \left[(1 - 2p_{l,n}) + j(1 - 2p_{l,n+K}) \right] \text{ for } n = 0, 1, 2, \dots, K-1.$$

14.6 Frequency interleaving

This clause defines the correspondence between the index n of the QPSK symbols $q_{l,n}$ and the carrier index k ($-K/2 \leq k < 0$ and $0 < k \leq K/2$).

The QPSK symbols shall be re-ordered according to the following relation:

$$y_{l,k} = q_{l,n} \text{ for } l = 2, 3, 4, \dots, L$$

with $k = F(n)$, where F is a function defined in the following clauses for the four transmission modes.

14.6.1 Transmission mode I

Let $\Pi(i)$ be a permutation in the set of integers $i = 0, 1, 2, \dots, 2047$ obtained from the following congruential relation:

$$\Pi(i) = 13 \Pi(i-1) + 511 \pmod{2048} \text{ and } \Pi(0) = 0;$$

for $i = 1, 2, \dots, 2047$.

$\Pi(i)$ defines a permutation of the ordered set $(0, 1, 2, \dots, 2047)$, resulting in the set:

$$A = \{\Pi(0), \Pi(1), \Pi(2), \dots, \Pi(2047)\}.$$

Let D be the set $D = \{d_0, d_1, d_2, \dots, d_{1535}\}$, containing 1536 elements and defined as being the subset of A with the same element ordering, comprising all the elements of A higher than or equal to 256 and lower than or equal to 1792, excluding 1024. Thus, if $\Pi(i)$ is the $(n+1)$ th element of A in the range [256, 1792] excluding 1024, $d_n = \Pi(i)$.

The correspondence between the index $n \in \{0, 1, 2, \dots, 1535\}$ of the QPSK symbol $q_{l,n}$ and the frequency index

$$k \in \{-768, -767, -766, \dots, 768\} \setminus \{0\},$$

shall be given by:

$$k = F(n) = d_n - 1024.$$

The function F is a one-to-one mapping between the sets $\{0, 1, 2, \dots, 1535\}$ and $\{-768, -767, -766, \dots, 768\} \setminus \{0\}$.

The interleaving rule is illustrated in table 44.

Table 44: Frequency interleaving for transmission mode I

i	$\Pi(i)$	d_n	n	k
0	0			
1	511	511	0	-513
2	1 010	1 010	1	-14
3	1 353	1 353	2	329
4	1 716	1 716	3	692
5	291	291	4	-733
6	198			
7	1 037	1 037	5	13
8	1 704	1 704	6	680
9	135			
10	218			
11	1 297	1 297	7	273
12	988	988	8	-36
13	1 076	1 067	9	43
14	46			
15	1 109	1 109	10	85
16	592	592	11	-432
17	15			
18	706	706	12	-318
:	:	:		
2044	1 676	1 676	1 533	652
2045	1 819			
2046	1 630	1 630	1 534	606
2047	1 221	1 221	1 535	197

14.6.2 Transmission mode II

Let $\Pi(i)$ be a permutation in the set of integers $i = 0, 1, 2, \dots, 511$ obtained from the following congruential relation:

$$\Pi(i) = 13 \Pi(i-1) + 127 \pmod{512} \text{ and } \Pi(0) = 0;$$

for $i = 1, 2, \dots, 511$.

$\Pi(i)$ defines a permutation of the ordered set $(0, 1, 2, \dots, 511)$, resulting in the set:

$$A = \{\Pi(0), \Pi(1), \Pi(2), \dots, \Pi(511)\}.$$

Let D be the set $D = \{d_0, d_1, d_2, \dots, d_{383}\}$, containing 384 elements and defined as being the subset of A with the same element ordering, comprising all the elements of A higher than or equal to 64 and lower than or equal to 448, excluding 256. Thus, if $\Pi(i)$ is the $(n+1)$ th element of A in the range [64, 448] excluding 256, $d_n = \Pi(i)$.

The correspondence between the index $n \in \{0, 1, 2, \dots, 383\}$ of the QPSK symbol $q_{l, n}$ and the frequency index $k \in \{-192, -191, -190, \dots, 192\} \setminus \{0\}$, shall be given by:

$$k = F(n) = d_n - 256.$$

The function F is a one-to-one mapping between the sets $\{0, 1, 2, \dots, 383\}$ and $\{-192, -191, -190, \dots, 192\} \setminus \{0\}$.

The interleaving rule is illustrated in table 45.

Table 45: Frequency interleaving for transmission mode II

i	$\Pi(i)$	d_n	n	k
0	0			
1	127	127	0	-129
2	242	242	1	-14
3	201	201	2	-55
4	180	180	3	-76
5	419	419	4	163
6	454			
7	397	397	5	141
8	168	168	6	-88
9	263	263	7	7
10	474			
11	145	145	8	-111
12	476			
13	171	171	9	-85
14	302	302	10	46
15	469			
16	80	80	11	-176
17	143	143	12	-113
18	450			
:	:	:		
508	140	140	380	-116
509	411	411	381	155
510	350	350	382	94
511	69	69	383	-187

14.6.3 Transmission mode III

Let $\Pi(i)$ be a permutation in the set of integers $i = 0, 1, 2, \dots, 255$ obtained from the following congruential relation:

$$\Pi(i) = 13 \Pi(i-1) + 63 \pmod{256} \text{ and } \Pi(0) = 0;$$

for $i = 1, 2, \dots, 255$.

$\Pi(i)$ defines a permutation of the ordered set $(0, 1, 2, \dots, 255)$, resulting in the set:

$$A = \{\Pi(0), \Pi(1), \Pi(2), \dots, \Pi(255)\}.$$

Let D be the set $D = \{d_0, d_1, d_2, \dots, d_{191}\}$, containing 192 elements and defined as being the subset of A with the same element ordering, comprising all the elements of A higher than or equal to 32 and lower than or equal to 224, excluding 128. Thus, if $\Pi(i)$ is the $(n+1)$ th element of A in the range $[32, 224]$ excluding 128, $d_n = \Pi(i)$.

The correspondence between the index $n \in \{0, 1, 2, \dots, 191\}$ of the QPSK symbol $q_{l, n}$ and the frequency index $k \in \{-96, -95, -94, \dots, 96\} \setminus \{0\}$, shall be given by:

$$k = F(n) = d_n - 128.$$

The function F is a one-to-one mapping between the sets $\{0, 1, 2, \dots, 191\}$ and $\{-96, -95, -94, \dots, 96\} \setminus \{0\}$.

The interleaving rule is illustrated in table 46.

Table 46: Frequency interleaving for transmission mode III

i	$\Pi(i)$	d_n	n	k
0	0			
1	63	63	0	-65
2	114	114	1	-14
3	9			
4	180	180	2	52
5	99	99	3	-29
6	70	70	4	-58
7	205	205	5	77
8	168	168	6	40
9	199	199	7	71
10	90	90	8	-38
11	209	209	9	81
12	220	220	10	92
13	107	107	11	-21
14	174	174	12	46
15	21			
16	80	80	13	-48
17	79	79	14	-49
18	66	66	15	-62
:	:	:		
252	140	140	188	12
253	91	91	189	-37
254	222	222	190	94
255	133	133	191	5

14.6.4 Transmission mode IV

Let $\Pi(i)$ be a permutation in the set of integers $i = 0, 1, 2, \dots, 1023$ obtained from the following congruential relation:

$$\Pi(i) = 13 \Pi(i-1) + 255 \pmod{1024} \text{ and } \Pi(0) = 0;$$

for $i = 1, 2, \dots, 1023$.

$\Pi(i)$ defines a permutation of the ordered set $(0, 1, 2, \dots, 1023)$, resulting in the set:

$$A = \{\Pi(0), \Pi(1), \Pi(2), \dots, \Pi(1023)\}.$$

Let D be the set $D = \{d_0, d_1, d_2, \dots, d_{767}\}$, containing 768 elements and defined as being the subset of A with the same element ordering, comprising all the elements of A higher than or equal to 128 and lower than or equal to 896, excluding 512. Thus, if $\Pi(i)$ is the $(n+1)$ th element of A in the range $[128, 896]$ excluding 512, $d_n = \Pi(i)$.

The correspondence between the index $n \in \{0, 1, 2, \dots, 767\}$ of the QPSK symbol $q_{l, n}$ and the frequency index $k \in \{-384, -383, -382, \dots, 384\} \setminus \{0\}$, shall be given by:

$$k = F(n) = d_n - 512.$$

The function F is a one-to-one mapping between the sets $\{0, 1, 2, \dots, 767\}$ and $\{-384, -383, -382, \dots, 384\} \setminus \{0\}$.

The interleaving rule is illustrated in table 47.

Table 47: Frequency interleaving for transmission mode IV

i	$\Pi(i)$	d_n	n	k
0	0			
1	255	255	0	-257
2	498	498	1	-14
3	585	585	2	73
4	692	692	3	180
5	35			
6	710	710	4	198
7	269	269	5	-243
8	680	680	6	168
9	903			
10	730	730	7	218
11	529	529	8	17
12	988			
13	811	811	9	299
14	558	558	10	46
15	341	341	11	-171
16	592	592	12	80
17	783	783	13	271
18	194	194	14	-318
:	:	:		
1 020	652	652	765	140
1 021	539	539	766	27
1 022	94			
1 023	453	453	767	-59

14.7 Differential modulation

Differential modulation shall be applied to the QPSK symbols on each carrier. The differential modulation is defined by the following rule:

$$z_{l,k} = z_{l-1,k} \cdot y_{l,k}$$

$$\text{for } l = 2, 3, 4, \dots, L$$

$$\text{and } -\frac{K}{2} \leq k \leq \frac{K}{2}$$

This means that each carrier is modulated using a $\pi/4$ -shift D-QPSK. All together, they form the main signal defined in clause 14.2.

As indicated in clause 14.2, the generation of the complex D-QPSK symbols $z_{m,l,k}$ does not depend on the transmission frame index m , which appears on the formula defining the main signal $s(t)$.

The main signal $s(t)$ is therefore defined for all values of t . It is generated from the D-QPSK symbols $z_{m,l,k}$ by the OFDM symbol generator of figure 78.

14.8 Transmitter Identification Information signal

The TII is conveyed in the synchronization channel. It provides unambiguous identification of each transmitter in a DAB network. The implementation of TII is optional.

When used in conjunction with Service Information as defined in clause 8.1.9, the TII feature may provide an estimate of the geographical position of the receiver. In particular, TII is used with the Frequency Information (FI) facility in a Single Frequency Network (SFN).

The TII signal shall fill the null symbol of each transmission frame comprising the CIFs of CIF count 0, 1, 2, 3 modulo 8 (transmission mode I), comprising the CIF of CIF count 0 modulo 2 (transmission modes II and III), and comprising the CIFs of CIF count 0,1 modulo 4 (transmission mode IV).

The TII signal consists of a certain number of pairs of adjacent carriers of an OFDM symbol; the actual selection of those carriers present in the TII symbol identifies the transmitter.

The selection of the carriers is defined by assigning two numbers to each transmitter; the pattern number p and the comb number c . These numbers are the Main Identifier and Sub-Identifier of a transmitter, respectively, and are used in the TII feature described in clause 8.1.9.

The TII signal $s_{TII}(t)$ associated with a given transmitter shall be:

$$s_{TII}(t) = \text{Re} \left\{ e^{2j\pi f_c t} \sum_{m=-\infty}^{+\infty} \sum_{k=-K/2}^{K/2} z_{m,0,k} \cdot g_{TII,k}(t - mT_F) \right\}$$

where:

$$g_{TII,k}(t) = e^{2\pi j k (t - T_{NULL} + T_U) / T_U} \cdot \text{Rect}(t / T_{NULL})$$

The parameters T_U , T_{NULL} and f_c are defined in clause 14.2; $z_{m,0,k}$ is the complex number associated to carrier k of the null symbol. It is equal to zero during the transmission frame m when the TII signal is not transmitted. Its values, for the transmission frame m where the TII signal is transmitted, shall be derived from the values of p and c .

The following relation is defined:

$$z_{m,0,k} = A_{c,p}(k) \cdot e^{j\varphi_k} + A_{c,p}(k-1) \cdot e^{j\varphi_{k-1}}$$

The values of φ_k are defined in clause 14.3.2. The values of $A_{c,p}(k)$ are specified in the following clauses.

14.8.1 Transmission modes I, II and IV

The following formulae shall apply:

Transmission mode I:

$$A_{c,p}(k) = \begin{cases} \sum_{b=0}^7 \delta(k, -768 + 2c + 48b) \cdot a_b(p) & \text{for } -768 \leq k < -384 \\ \sum_{b=0}^7 \delta(k, -384 + 2c + 48b) \cdot a_b(p) & \text{for } -384 \leq k < 0 \\ \sum_{b=0}^7 \delta(k, 1 + 2c + 48b) \cdot a_b(p) & \text{for } 0 < k \leq 384 \\ \sum_{b=0}^7 \delta(k, 385 + 2c + 48b) \cdot a_b(p) & \text{for } 384 < k \leq 768 \end{cases}$$

and $A_{c,p}(0) = A_{c,p}(-769) = 0$.

This formula shall apply for $0 \leq c \leq 23$.

$a_b(p)$ is defined in table 48. δ is the Kronecker symbol defined in clause 3.3.

Transmission mode II:

$$A_{c,p}(k) = \sum_{b=0}^3 \delta(k, -192 + 2c + 48b) \cdot a_b(p) + \sum_{b=4}^7 \delta(k, -191 + 2c + 48b) \cdot a_b(p)$$

and $A_{c,p}(-193) = 0$.

This formula shall apply for $0 \leq c \leq 23$.

$a_b(p)$ is defined in table 48. δ is the Kronecker symbol defined in clause 3.3.

Transmission mode IV:

$$A_{c,p}(k) = \begin{cases} \sum_{b=0}^7 \delta(k, -384 + 2c + 48b) \cdot a_b(p) & \text{for } -384 \leq k < 0 \\ \sum_{b=0}^7 \delta(k, 1 + 2c + 48b) \cdot a_b(p) & \text{for } 0 < k \leq 384 \end{cases}$$

and $A_{c,p}(0) = A_{c,p}(-385) = 0$.

This formula shall apply for $0 \leq c \leq 23$.

$a_b(p)$ is defined in table 48. δ is the Kronecker symbol defined in clause 3.3.

Table 48: TII pattern for transmission modes I, II and IV

p	$a_b(p)$ b=0,1,2,3,4,5,6,7	p	$a_b(p)$ b=0,1,2,3,4,5,6,7	p	$a_b(p)$ b=0,1,2,3,4,5,6,7
0	0 0 0 0 1 1 1 1	24	0 1 0 1 1 1 0 0	48	1 0 1 0 1 0 0 1
1	0 0 0 1 0 1 1 1	25	0 1 1 0 0 0 1 1	49	1 0 1 0 1 0 1 0
2	0 0 0 1 1 0 1 1	26	0 1 1 0 0 1 0 1	50	1 0 1 0 1 1 0 0
3	0 0 0 1 1 1 0 1	27	0 1 1 0 0 1 1 0	51	1 0 1 1 0 0 0 1
4	0 0 0 1 1 1 1 0	28	0 1 1 0 1 0 0 1	52	1 0 1 1 0 0 1 0
5	0 0 1 0 0 1 1 1	29	0 1 1 0 1 0 1 0	53	1 0 1 1 0 1 0 0
6	0 0 1 0 1 0 1 1	30	0 1 1 0 1 1 0 0	54	1 0 1 1 1 0 0 0
7	0 0 1 0 1 1 0 1	31	0 1 1 1 0 0 0 1	55	1 1 0 0 0 0 1 1
8	0 0 1 0 1 1 1 0	32	0 1 1 1 0 0 1 0	56	1 1 0 0 0 1 0 1
9	0 0 1 1 0 0 1 1	33	0 1 1 1 0 1 0 0	57	1 1 0 0 0 1 1 0
10	0 0 1 1 0 1 0 1	34	0 1 1 1 1 0 0 0	58	1 1 0 0 1 0 0 1
11	0 0 1 1 0 1 1 0	35	1 0 0 0 0 1 1 1	59	1 1 0 0 1 0 1 0
12	0 0 1 1 1 0 0 1	36	1 0 0 0 1 0 1 1	60	1 1 0 0 1 1 0 0
13	0 0 1 1 1 0 1 0	37	1 0 0 0 1 1 0 1	61	1 1 0 1 0 0 0 1
14	0 0 1 1 1 1 0 0	38	1 0 0 0 1 1 1 0	62	1 1 0 1 0 0 1 0
15	0 1 0 0 0 1 1 1	39	1 0 0 1 0 0 1 1	63	1 1 0 1 0 1 0 0
16	0 1 0 0 1 0 1 1	40	1 0 0 1 0 1 0 1	64	1 1 0 1 1 0 0 0
17	0 1 0 0 1 1 0 1	41	1 0 0 1 0 1 1 0	65	1 1 1 0 0 0 0 1
18	0 1 0 0 1 1 1 0	42	1 0 0 1 1 0 0 1	66	1 1 1 0 0 0 1 0
19	0 1 0 1 0 0 1 1	43	1 0 0 1 1 0 1 0	67	1 1 1 0 0 1 0 0
20	0 1 0 1 0 1 0 1	44	1 0 0 1 1 1 0 0	68	1 1 1 0 1 0 0 0
21	0 1 0 1 0 1 1 0	45	1 0 1 0 0 0 1 1	69	1 1 1 1 0 0 0 0
22	0 1 0 1 1 0 0 1	46	1 0 1 0 0 1 0 1		
23	0 1 0 1 1 0 1 0	47	1 0 1 0 0 1 1 0		

Figure 87 illustrates the result of this procedure in transmission mode II for $c = 4$ and $p = 16$.

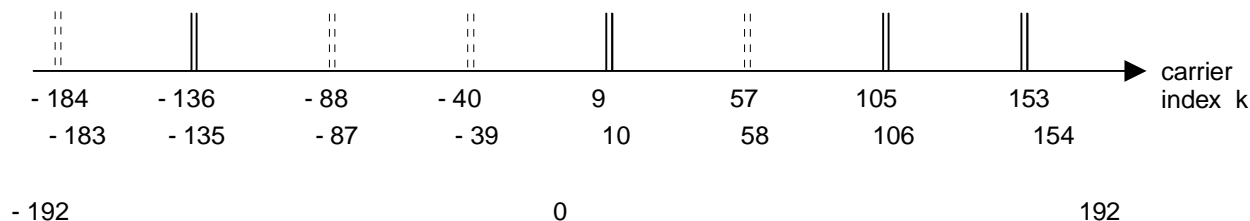


Figure 87: Example of TII signal in transmission mode II

In the example shown in figure 87, all the pairs of carriers shown belong to the comb of number $c = 4$. Only those shown by a full line are actually transmitted, because they belong to the set of carriers defined by the pattern number $p = 16$.

14.8.2 Transmission mode III

The following formula shall apply:

$$A_{c,p}(k) = \sum_{b=0}^1 \delta(k, -96 + 2c + 48b) \cdot a_b(p) + \sum_{b=2}^3 \delta(k, -95 + 2c + 48b) \cdot a_b(p)$$

and $A_{c,p}(-97) = 0$.

This formula shall apply for $0 \leq c \leq 23$.

$a_b(p)$ is defined in table 49. δ is the Kronecker symbol defined in clause 3.3.

Table 49: TII pattern for transmission mode III

p	$a_b(p)$ b=0,1,2,3
0	0 0 1 1
1	0 1 0 1
2	0 1 1 0
3	1 0 0 1
4	1 0 1 0
5	1 1 0 0

15 Radio frequency characteristics

This clause defines the preferred choice of the transmission mode as a function of the system operating conditions.

It also indicates the nominal characteristics of the DAB transmission signal at the radio frequency level, and specifies the permitted values of the central frequency. The consequences of pre-filtering and non-linear amplification on the time and spectrum characteristics of the signal, as well as on the performance of the system, are not included here.

15.1 Use of the transmission modes

The preferred choice of the transmission modes is dependent on the system operating conditions.

Transmission mode I is intended to be used for terrestrial Single Frequency Networks (SFN) and local-area broadcasting in Bands I, II and III.

Transmission modes II and IV are intended to be used for terrestrial local broadcasting in Bands I, II, III, IV, V and in the 1 452 MHz to 1 492 MHz frequency band (i.e. L-Band). It can also be used for satellite-only and hybrid satellite-terrestrial broadcasting in L-Band.

Transmission mode III is intended to be used for terrestrial, satellite and hybrid satellite-terrestrial broadcasting below 3 000 MHz.

For cable distribution, transmission mode III is the preferred mode because it can be used at any frequency available on cable. However, transmission modes I, II and IV may also be used, depending on the chosen frequency band.

15.2 Time characteristics

The DAB transmission signal consists of a succession of consecutive transmission frames of 96 ms duration for transmission mode I, 24 ms duration for transmission modes II and III, and 48 ms duration for transmission mode IV.

The synchronization channel occupies the first 5 208 elementary periods (approximately 2,543 ms) for transmission mode I, 1 302 elementary periods (approximately 0,636 ms) for transmission mode II, 664 elementary periods (approximately 0,324 ms) for transmission mode III, and 2 604 elementary periods (approximately 1,271 ms) for transmission mode IV. The elementary period is $1/2\ 048\ 000$ s (see clause 14.2).

The modulated OFDM symbols, corresponding to the FIC and the MSC, occupy the remaining portion of the transmission frame. These are approximately 93,457 ms for transmission mode I, approximately 23,364 ms for transmission mode II, approximately 23,676 ms for transmission mode III, and approximately 46,729 ms for transmission mode IV.

The synchronization channel conveys a fixed pattern as defined in clause 14.

The modulated OFDM symbols, as a sum of equally-spaced orthogonal carriers with independent phases, exhibit a Gaussian-like amplitude distribution.

15.3 Spectrum characteristics

The synchronization channel, repeated at the transmission frame rate, constitutes a fixed pattern described in clause 14, during which the transmitted signal is the juxtaposition of equally-spaced orthogonal carriers, with fixed amplitudes and phases.

The modulated OFDM symbols constitutes a juxtaposition of equally-spaced orthogonal carriers, with constant amplitude and time varying independent phases, resulting from the modulation procedure described in clause 14.

The power spectral density $P_k(f)$ of each carrier at frequency $f_k = f_c + k/T_u$.

($-K/2 \leq k < 0$ and $0 < k \leq K/2$) is defined by the following expression:

$$P_k(f) = \left[\frac{\sin \pi(f - f_k)T_s}{\pi(f - f_k)T_s} \right]^2$$

The overall power spectral density of the modulated symbols is the sum of the power spectral densities of all the carriers. Because the OFDM symbol duration is larger than the inverse of the carrier spacing, the main lobe of the power spectral density of each carrier is narrower than twice the carrier spacing. The theoretical DAB transmission signal spectra are illustrated in figures 88 to 91 for transmission modes I, II, III and IV respectively.

The level of the signal at frequencies outside the nominal 1,536 MHz bandwidth can be reduced by applying an appropriate filtering. The degree of suppression required of the side lobes shown in figures 88 to 91 will depend on the network configuration chosen and frequency co-ordination criteria with other transmissions.

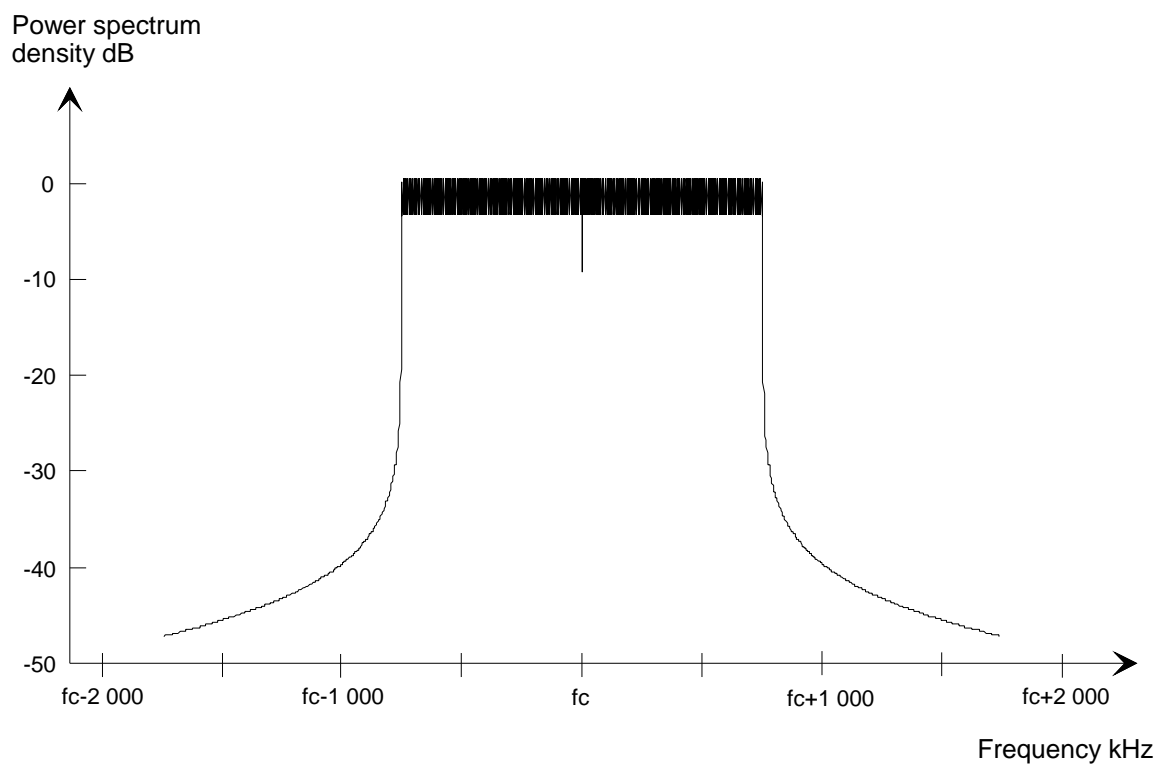


Figure 88: Theoretical DAB transmission signal spectrum for transmission mode I

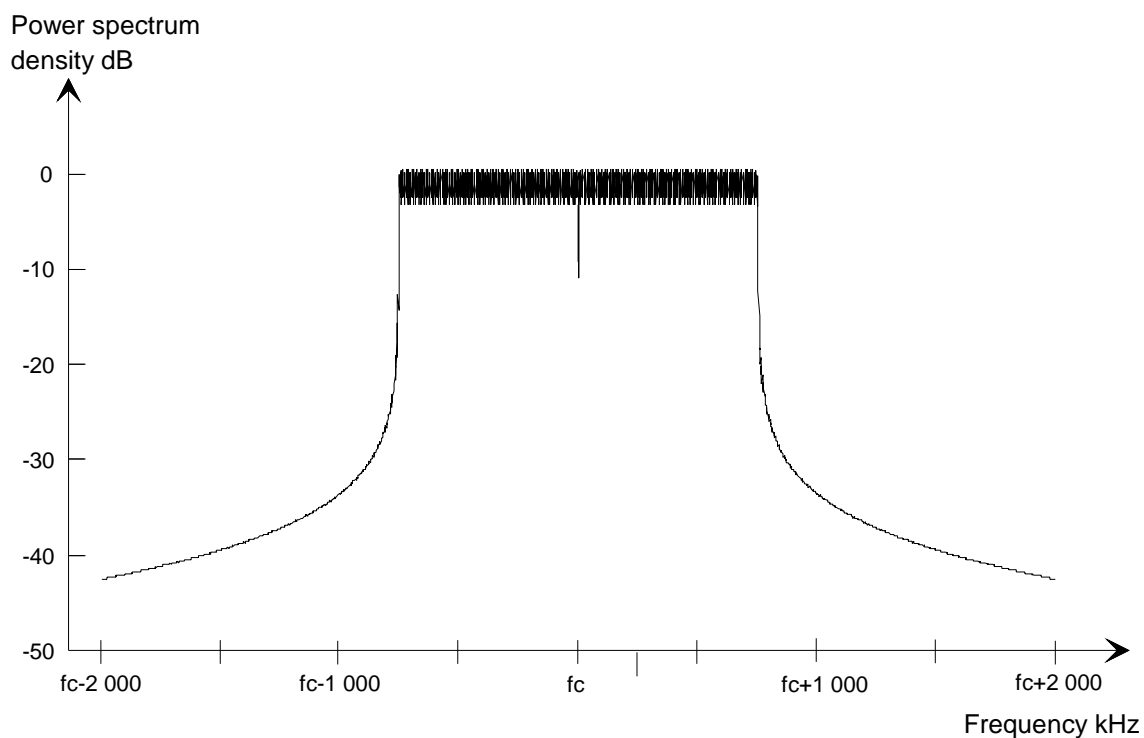


Figure 89: Theoretical DAB transmission signal spectrum for transmission mode II

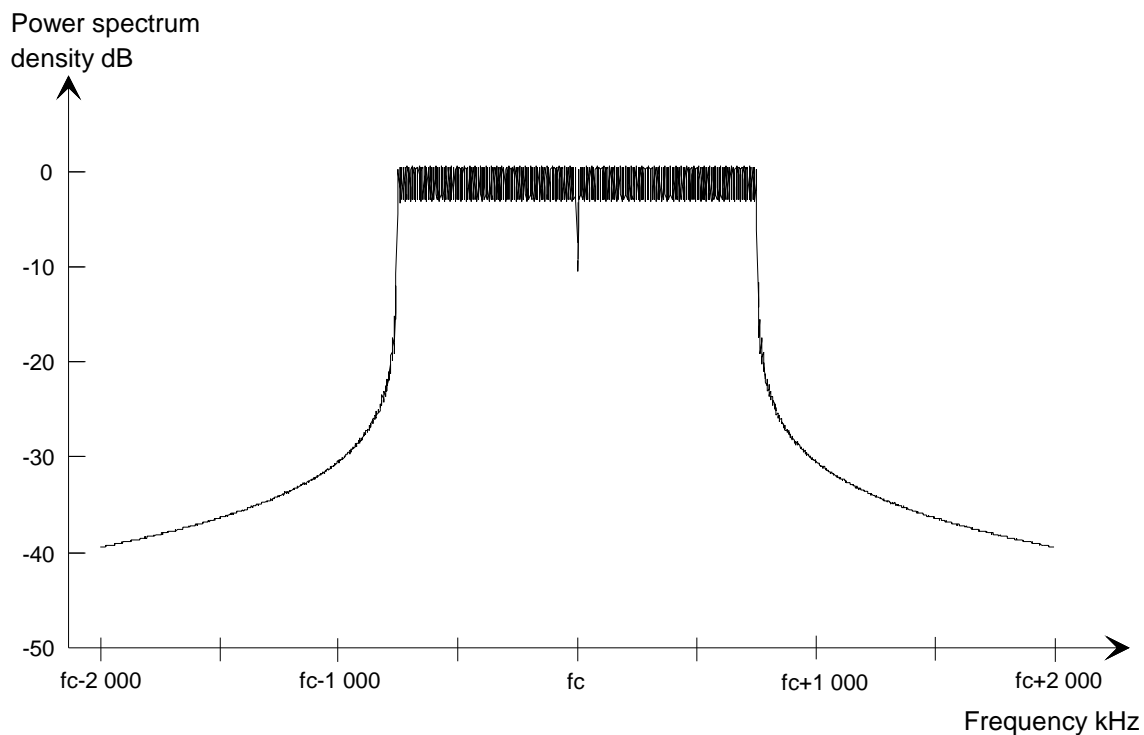


Figure 90: Theoretical DAB transmission signal spectrum for transmission mode III

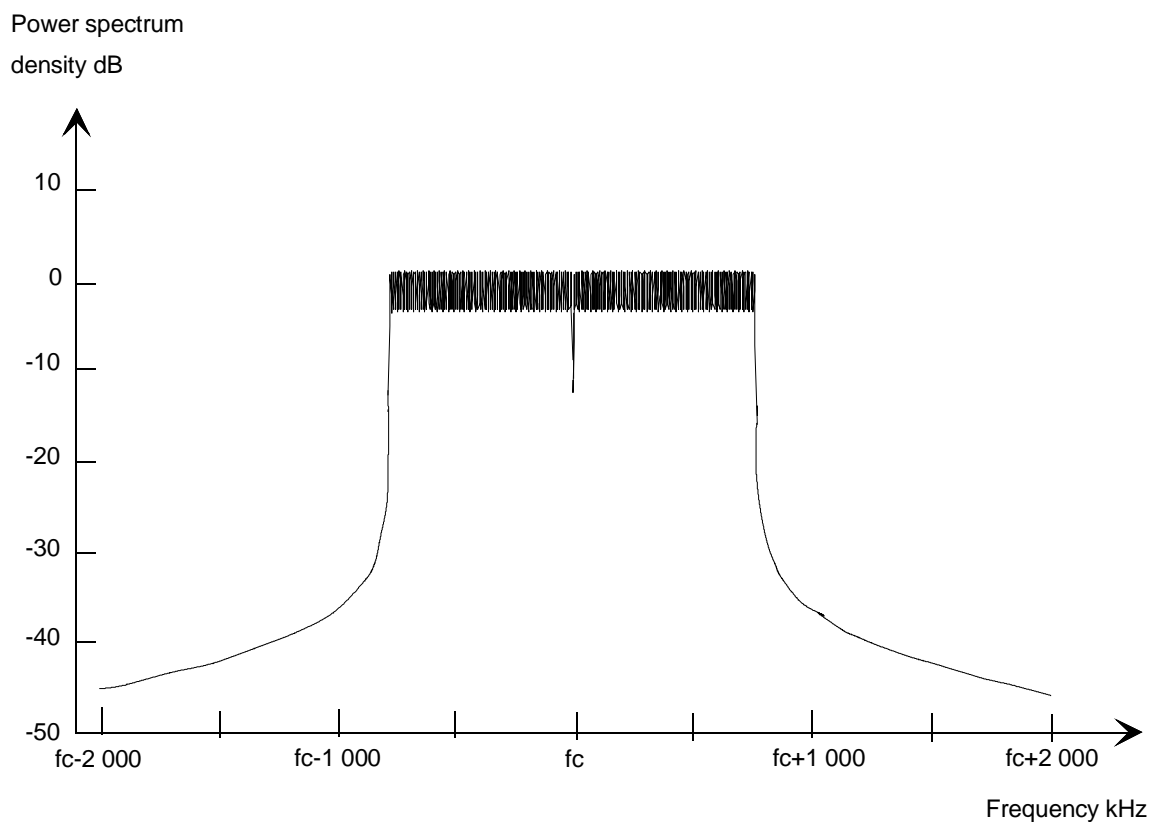
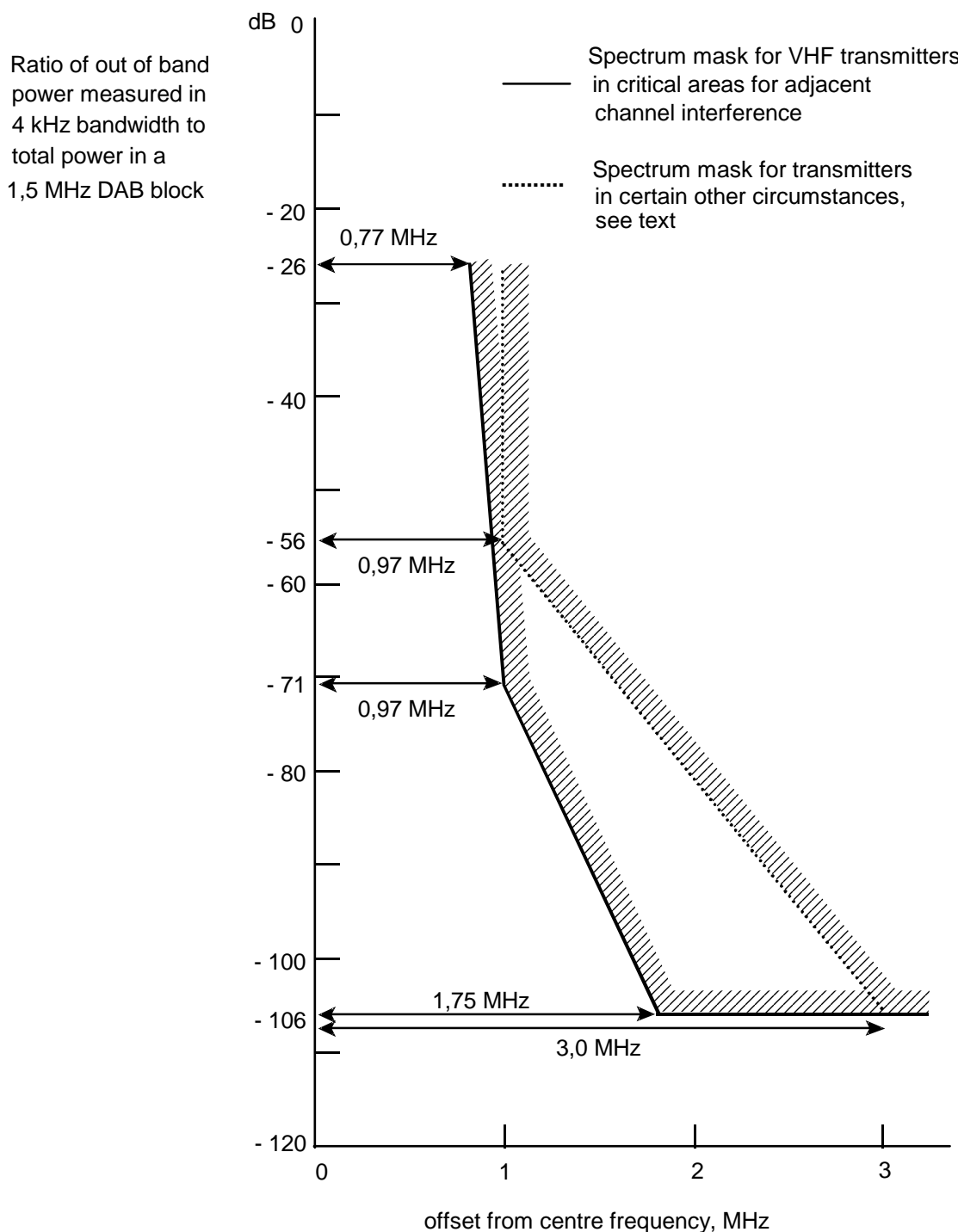


Figure 91: Theoretical DAB transmission signal spectrum for transmission mode IV

15.4 Spectrum mask

The out-of-band radiated signal spectrum in any 4 kHz band shall be constrained by one of the masks defined in figure 92.

The solid line mask shall apply to VHF transmitters in critical areas for adjacent channel interference. The dotted line mask shall apply to VHF transmitters in other circumstances and to UHF transmitters in critical cases for adjacent channel interference.



NOTE: Countries which were signatories at the CEPT T-DAB Planning meeting, held at Wiesbaden in September 1995 [13], have agreed to abide by spectrum masks for T-DAB out-of-band emissions as specified in the Final Acts, Annex 2, clause 2.3.1 [13]. These spectrum masks imply additional restrictions which continue below -106 dB.

Figure 92: Out-of-band spectrum mask for DAB transmission signal (all transmission modes)

15.5 Permitted values of the central frequency

The nominal central frequency f_c shall be an exact multiple of 16 kHz.

The actual central frequency may be offset by up to $\pm 1/2$ carrier spacing ($1/T_u$) in any transmission mode, where necessary, to improve spectrum sharing.

Annex A (informative): Main characteristics of the audio coding system

A.1 Audio signal characteristics

The main characteristics of the input audio signal are:

- **audio bandwidth:** For $f_s = 48$ kHz the input audio signal can cover the whole audio frequency range up to 20,3 kHz, and for $f_s = 24$ kHz the input audio signal is low-pass filtered before downsampling to 24 kHz to cover a restricted audio frequency range up to about 11,3 kHz;
- **audio Interface:** the digital input signal may conform to the AES/EBU interface specification (see IEC 60958 [9]);
- **input resolution:** the system can support any input resolution up to 22 bits/sample;
- **sampling frequency:** The sampling frequency of the input audio signal prior to encoding at the transmitting end and of a digital output audio signal after decoding at the DAB receiving end is 48 kHz. In the case of MPEG-2 Layer II LSF coding, downsampling from 48 kHz to 24 kHz is applied at the transmitting end, and upsampling from 24 kHz to 48 kHz is applied at the receiving end, in order to avoid any other sampling frequency than 48 kHz for the PCM audio input and output signal.

A.2 Audio coding characteristics

The main characteristics of the audio coding system are:

- **audio modes:** four audio modes are provided:
 - single channel mode (one monophonic audio programme);
 - stereo mode (left and right channels of a stereophonic audio programme);
 - dual channel mode. In this mode, the two audio channels can be either bilingual, or two mono channels;
 - joint stereo mode. In this mode, the encoder exploits redundancy and irrelevancy of stereo signals for further data reduction, using Intensity stereo coding.
- **bit rate:** According to ISO/IEC 11172-3 [3] Layer II, the permitted bit rates of the encoded audio signal for the sampling frequency of 48 kHz in single channel mode are as follows:
 - 32 kbit/s, 48 kbit/s, 56 kbit/s, 64 kbit/s, 80 kbit/s, 96 kbit/s, 112 kbit/s, 128 kbit/s, 160 kbit/s and 192 kbit/s.

The stereo, dual channel and joint stereo modes use twice the bit rate of the single channel mode (see also tables 20 and 22 in clause 7.2.1.3).

- According to ISO/IEC 13818-3 [11] Layer II, the permitted bit rates of the encoded audio signal for the sampling frequency of 24 kHz, irrespective of the audio mode, are as follows:
 - 8 kbit/s, 16 kbit/s, 24 kbit/s, 32 kbit/s, 40 kbit/s, 48 kbit/s, 56 kbit/s, 64 kbit/s, 80 kbit/s, 96 kbit/s, 112 kbit/s, 128 kbit/s, 144 kbit/s and 160 kbit/s (see also table 20 in clause 7.2.1.3).
- **DAB audio frame length:** One DAB audio frame covers 1152 PCM audio samples. For 48 kHz sampling frequency the length of a DAB audio frame is 24 ms. For 24 kHz sampling frequency the length of a DAB audio frame is 48 ms. This is twice the length of a DAB audio frame according to MPEG-1 Audio Layer II (ISO/IEC 11172-3 [3]). The DAB LSF audio frame is divided into two parts of equal lengths, an even (subframe "0", containing the first part of the DAB LSF audio frame) and an odd subframe (subframe "1", containing the second part of the DAB LSF audio frame), both fitting perfectly into the frame structure of the DAB logical frames. The X-PAD and F-PAD are available only once per 48 ms period.

A.3 Audio associated data characteristics

Programme Associated Data

Each DAB audio frame contains a number of bytes specifically for carrying Programme Associated Data (PAD). At the end of the DAB audio frame, a capacity of at least two bytes, called Fixed Programme Associated Data (F-PAD), is provided, irrespective of the sampling frequency, bit rate or the audio mode (i.e. single channel, stereo and dual channel modes will all have the same capacity of F-PAD). But the broadcaster may choose to extend this capacity, called Extended Programme Associated Data (X-PAD) in order to transmit more audio related data.

These PAD comprise mainly information which are intimately associated with the audio signal, and which would become useless if delayed in a queue with other data, or if removed from the channel-coded audio bit stream and sent in a separate data service component. By reserving the limited capacity available for the PAD for information satisfying these criteria, it is possible to make the most effective use of such a data channel, which is strongly linked with the encoded audio signal. Although some capacity of X-PAD can also be provided for programme service information, further capacity can be provided elsewhere in the DAB multiplex (or ensemble) to carry additional information, such as text, relating to the various programmes in the ensemble which may require this, or some similar, facility.

It has to be considered that in the LSF mode the bit rate of F-PAD is reduced by a factor of two compared to the full sampling frequency mode, defined in the present document. Therefore, for a sampling frequency of 48 kHz, a bit rate of 0,667 kbit/s is available for F-PAD, but for a sampling frequency of 24 kHz, only 0,333 kbit/s are available for F-PAD.

Error protection of PAD when UEP error protection is used

The F-PAD and some parts of X-PAD are more strongly protected by the convolutional code of the transmission system than most of the other parts of the DAB audio bit stream (see clause 11). These fields are protected with different code-rates due to the Unequal Error Protection (UEP). Compared to the audio sub-band samples, a higher protection applies to F-PAD and four bytes of X-PAD. Depending on the requirement of the different types of PAD, this protection may be supplemented by additional protection schemes.

A.4 Functions provided by PAD

The following functions are provided by F-PAD:

- **Dynamic Range Control:** with the help of the Dynamic Range Control (DRC) the receiver may reduce the dynamic range of the audio signal. The purpose of this is to adapt the dynamic range of the audio signal to listening in a noisy environment.

In order to provide the dynamic range compression facility for receivers requiring the DRC signal, the audio programme is examined in a compression processor on the broadcasters premises, which derives the DRC signal, but does not apply any compression to the audio. The DRC signal, which controls a variable-gain amplifier or an equivalent digital processor in the receiver, is sent to the receiver in the Fixed Programme Associated Data (F-PAD), see clause 7.4.1.1.

- **Music/Speech indication:** two bits representing the Music/Speech flags indicate whether the transmitted sound consists of music or speech. The receiver may use this information to control any sound processing circuitry. One special combination of the flags signals that no indication is given. The Music/Speech indication should be transmitted at least for 4 consecutive DAB audio frames and repeated at intervals of no more than 0,5 second.
- **Command channel:** a channel can be provided to convey, synchronously to the music, special commands to the decoder. Such commands may be used, for instance, to trigger the read out of a picture from a buffer memory that was filled, asynchronously, in advance. This channel is able to carry a few bytes within 0,2 second to 0,5 second, at irregular intervals.
- **ISRC and UPC/EAN:** ISO 3901 [8] and the Universal Product Code/European Article Number (see EN 797 [12]) are provided by (some) digital carriers of pre-recorded software. Transmission of ISRC and UPC/EAN requires 10 bits per second.

- **In-house information:** channels can be provided for both short, synchronous commands and for long strings of asynchronous data. The meaning of these commands and data is not subject to standardization, as it is intended for internal use within the broadcast chain only.

For a sampling frequency of 48 kHz F-PAD is transmitted every 24 ms, corresponding to the frame structure of the DAB Main Service Channel. However, for 24 kHz sampling frequency, with the DAB LSF audio frame subdivided into two subframes of equal lengths, PAD is transmitted only once per 48 ms period. Any audio encoding device, which inserts PAD, needs to know whether the present sub-frame is the even or the odd one, whereby PAD is inserted only in the odd subframe.

Annex B (normative): Audio decoding

B.1 General

The first action is synchronization of the decoder to the incoming audio bit stream, just after start-up. This may be done by using an external hardware synchronization signal, which is provided by the COFDM channel-demodulator every 24 ms, and thus enables the synchronization in the case of 48 kHz sampling frequency. However, in the case of 24 kHz sampling frequency, the DAB audio frame length is 48 ms, subdivided into two subframes of equal lengths, and the frame start is valid only every second time this external signal is provided. In this case, after start-up, the synchronization of the audio decoder is done by searching in the encoded audio bit stream for the MPEG Audio 12 bit syncword which is conveyed in each even subframe (subframe "0") and which can be compared with the external hardware synchronization signal, thereby allowing an extremely reliable synchronization.

In the DAB application, some parts of the ISO/IEC 11172-3 [3] header information, which are still kept in the DAB audio frame header, are already known to the decoder and need not to be decoded. These are layer, protection_bit, sampling_frequency, padding_bit, private bit and emphasis.

In addition to the ID bit, bitrate_index bits, copyright bit and original/copy bit, the decoder shall read the mode bits, and if these equal "01" also the mode_extension bits. The mode_extension bits set the "bound" as shown in clause 7.2 and thus indicate which sub-bands are coded in the Intensity stereo mode.

B.2 CRC check for audio side information

A CRC-check word for detecting errors within the significant side information of a DAB audio frame has been inserted in the bit stream just after the DAB audio frame header. The error detection method used is "CRC-16" whose generator polynomial is:

$$G_I(x) = x^{16} + x^{15} + x^2 + 1$$

The bits included into the CRC-check are:

- 16 bits of DAB_audio_frame_header(), starting with bit_rate_index and ending with emphasis;
- a number of bits of audio_data(), starting with the first bit. These bits include bit allocation information and ScFSI.

The method for the calculation of the CRC word in the decoder is described in annex E. The initial state of the shift register is "1111 1111 1111 1111". If the final output of the shift register and the CRC-check word in the DAB audio frame are not identical, a transmission error has occurred in the protected field of the audio bit stream.

B.3 CRC check for Scale Factors

For detection of errors within the three MSB's of the Scale Factors, CRC-check words shall be inserted in the DAB audio bit stream just in front of the F-PAD field of the preceding DAB audio frame. For 48 kHz sampling frequency coding according to ISO/IEC 11172-3 [3] Layer II, either two or four CRC-check words shall be used, dependent on the bit rate. The CRC-check words are covering the Scale Factors of the following sub-bands:

If the bit rate per channel is greater than or equal to 56 kbit/s (i.e. bit rate \geq 56 kbit/s for single channel mode, bit rate \geq 112 kbit/s for all other modes):

- ScF-CRC0: Sub-bands 0 to 3 (sub-band group 0);
- ScF-CRC1: Sub-bands 4 to 7 (sub-band group 1);

- ScF-CRC2: Sub-bands 8 to 15 (sub-band group 2);
- ScF-CRC3: Sub-bands 16 to 26 (sub-band group 3).

If the bit rate per channel is less than 56 kbit/s (i.e. bit rate < 56 kbit/s for single channel mode, bit rate < 112 kbit/s for other audio modes):

- ScF-CRC0: Sub-bands 0 to 3 (sub-band group 0);
- ScF-CRC1: Sub-bands 4 to 7 (sub-band group 1).

To keep the position of the ScF-CRC-check words 1 and 2 independent of the bit rate, the ScF-CRC-check words are put in reverse order in the bit stream:

- ScF-CRC3, ScF-CRC2, ScF-CRC1, ScF-CRC0 bitrate \geq 56 kbit/s/ch;
- ScF-CRC1, ScF-CRC0 bitrate < 56 kbit/s/ch.

For 24 kHz sampling frequency coding according to ISO/IEC 13818-3 [11] Layer II, always four CRC-check words shall be used. The CRC-check words are covering the Scale Factors of the following sub-bands:

- ScF-CRC0: Sub-bands 0 to 3 (sub-band group 0);
- ScF-CRC1: Sub-bands 4 to 7 (sub-band group 1);
- ScF-CRC2: Sub-bands 8 to 15 (sub-band group 2);
- ScF-CRC3: Sub-bands 16 to 29 (Sub-band group 3).

As in the case of 48 kHz sampling frequency coding, the ScF-CRC-check words are put in reverse order in the bit stream:

- ScF-CRC3, ScF-CRC2, ScF-CRC1, ScF-CRC0.

The error detection method used is "CRC-8", whose generator polynomial is:

$$G_2(X) = x^8 + x^4 + x^3 + x^2 + 1$$

For both, 48 kHz and 24 kHz sampling frequency coding, the bits included in the CRC-check are the 3 MSBs of all Scale Factors of the sub-band group, according to their order in the bit stream.

The method for the calculation of the ScF-CRC word is the same as for the CRC word in clause B.2, and is described in annex E. The initial state of this shift register however is "0000 0000". If the output of the shift register and the transmitted ScF-CRC-check words are not identical, a transmission error has occurred in the three MSBs of one of the Scale Factors of this special sub-band group.

B.4 Decoding of the MPEG Audio Layer II bit stream

For 48 kHz and 24 kHz sampling frequency coding, the principles of the decoding process are given in ISO/IEC 11172-3 [3], chapter 2.4.3.3. In the case of 48 kHz sampling frequency, either tables 14 or 15 (bit allocation and possible quantization per sub-band) shall be used, dependent on the bit rate and audio mode, whereas in the case of 24 kHz sampling frequency, always table 15 (bit allocation and possible quantization per sub-band) shall be used.

Annex C (informative): Audio encoding

C.1 Analysis sub-band filter

The first step in the encoding process of a broadband PCM audio signal should be the filtering into 32 equally spaced sub-bands, each of which is down-sampled by a factor of $f_s/32$. The flow chart of this iterative process with the appropriate formulas is given in figure C.1. The analysis sub-band filtering includes the following steps:

- input 32 PCM audio samples;
- build an input sample vector X of 512 elements, so that the 512 most recent PCM audio samples are stored in the vector X . In each iteration 32 PCM audio samples are shifted in at positions 0 to 31, the most recent on at position 0, and the 32 oldest samples are shifted out. Position 0 of the vector X always contains the most recent sample, and position 511 the oldest one;
- vector X is windowed by vector C . The coefficients C_i are to be found in the table C.1;
- calculate the 64 intermediate values Y_j according to the formula given in the analysis filter flow chart;
- the 32 sub-band samples S_j are calculated by matrixing. The coefficients for the matrix M can be calculated by the following formula:

$$M_{ik} = \cos [(2i + 1)(k - 16)\pi/64] \quad 0 \leq i \leq 31, 0 \leq k \leq 63$$

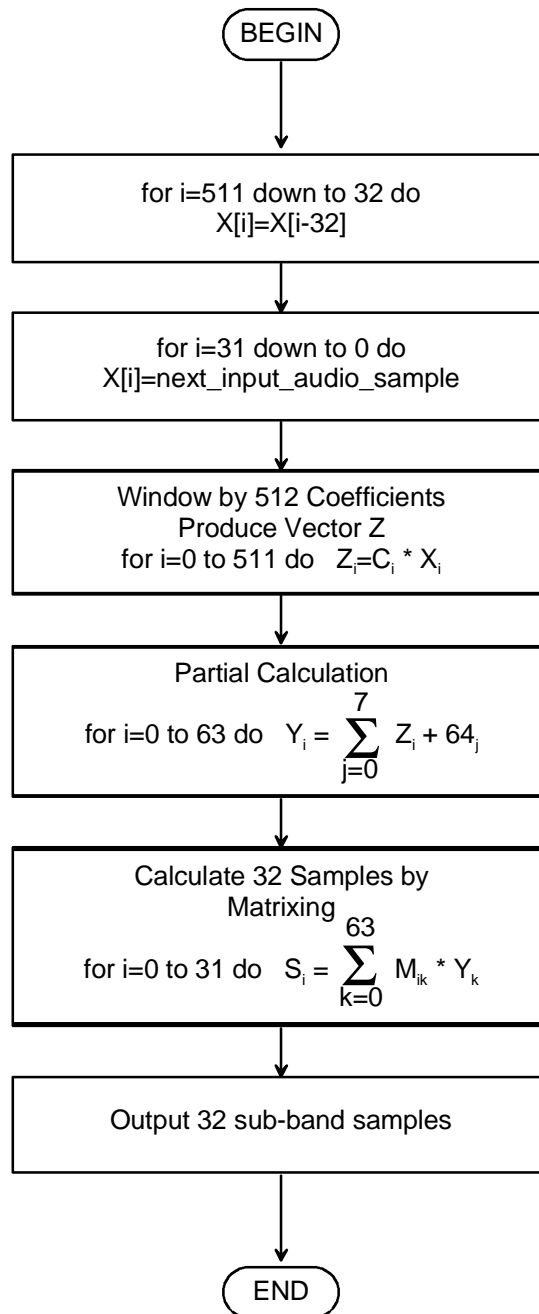


Figure C.1: Analysis sub-band filter flow chart

Table C.1: Coefficients C_i of the analysis window

C[0]= 0,000000000	C[1]=-0,000000477	C[2]=-0,000000477	C[3]=-0,000000477
C[4]=-0,000000477	C[5]=-0,000000477	C[6]=-0,000000477	C[7]=-0,000000954
C[8]=-0,000000954	C[9]=-0,000000954	C[10]=-0,000000954	C[11]=-0,000001431
C[12]=-0,000001431	C[13]=-0,000001907	C[14]=-0,000001907	C[15]=-0,000002384
C[16]=-0,000002384	C[17]=-0,000002861	C[18]=-0,000003338	C[19]=-0,000003338
C[20]=-0,000003815	C[21]=-0,000004292	C[22]=-0,000004768	C[23]=-0,000005245
C[24]=-0,000006199	C[25]=-0,000006676	C[26]=-0,000007629	C[27]=-0,000008106
C[28]=-0,000009060	C[29]=-0,000010014	C[30]=-0,000011444	C[31]=-0,000012398
C[32]=-0,000013828	C[33]=-0,000014782	C[34]=-0,000016689	C[35]=-0,000018120
C[36]=-0,000019550	C[37]=-0,000021458	C[38]=-0,000023365	C[39]=-0,000025272
C[40]=-0,000027657	C[41]=-0,000030041	C[42]=-0,000032425	C[43]=-0,000034809
C[44]=-0,000037670	C[45]=-0,000040531	C[46]=-0,000043392	C[47]=-0,000046253
C[48]=-0,000049591	C[49]=-0,000052929	C[50]=-0,000055790	C[51]=-0,000059605
C[52]=-0,000062943	C[53]=-0,000066280	C[54]=-0,000070095	C[55]=-0,000073433
C[56]=-0,000076771	C[57]=-0,000080585	C[58]=-0,000083923	C[59]=-0,000087261
C[60]=-0,000090599	C[61]=-0,000093460	C[62]=-0,000096321	C[63]=-0,000099182
C[64]= 0,000101566	C[65]= 0,000103951	C[66]= 0,000105858	C[67]= 0,000107288
C[68]= 0,000108242	C[69]= 0,000108719	C[70]= 0,000108719	C[71]= 0,000108242
C[72]= 0,000106812	C[73]= 0,000105381	C[74]= 0,000102520	C[75]= 0,000099182
C[76]= 0,000095367	C[77]= 0,000090122	C[78]= 0,000084400	C[79]= 0,000077724
C[80]= 0,000069618	C[81]= 0,000060558	C[82]= 0,000050545	C[83]= 0,000039577
C[84]= 0,000027180	C[85]= 0,000013828	C[86]=-0,000000954	C[87]=-0,000017166
C[88]=-0,000034332	C[89]=-0,000052929	C[90]=-0,000072956	C[91]=-0,000093937
C[92]=-0,000116348	C[93]=-0,000140190	C[94]=-0,000165462	C[95]=-0,000191212
C[96]=-0,000218868	C[97]=-0,000247478	C[98]=-0,000277042	C[99]=-0,000307560
C[100]=-0,000339031	C[101]=-0,000371456	C[102]=-0,000404358	C[103]=-0,000438213
C[104]=-0,000472546	C[105]=-0,000507355	C[106]=-0,000542164	C[107]=-0,000576973
C[108]=-0,000611782	C[109]=-0,000646591	C[110]=-0,000680923	C[111]=-0,000714302
C[112]=-0,000747204	C[113]=-0,000779152	C[114]=-0,000809669	C[115]=-0,000838757
C[116]=-0,000866413	C[117]=-0,000891685	C[118]=-0,000915051	C[119]=-0,000935555
C[120]=-0,000954151	C[121]=-0,000968933	C[122]=-0,000980854	C[123]=-0,000989437
C[124]=-0,000994205	C[125]=-0,000995159	C[126]=-0,000991821	C[127]=-0,000983715
C[128]= 0,000971317	C[129]= 0,000953674	C[130]= 0,000930786	C[131]= 0,000902653
C[132]= 0,000868797	C[133]= 0,000829220	C[134]= 0,000783920	C[135]= 0,000731945
C[136]= 0,000674248	C[137]= 0,000610352	C[138]= 0,000539303	C[139]= 0,000462532
C[140]= 0,000378609	C[141]= 0,000288486	C[142]= 0,000191689	C[143]= 0,000088215
C[144]=-0,000021458	C[145]=-0,000137329	C[146]=-0,000259876	C[147]=-0,000388145
C[148]=-0,000522137	C[149]=-0,000661850	C[150]=-0,000806808	C[151]=-0,000956535
C[152]=-0,001111031	C[153]=-0,001269817	C[154]=-0,001432419	C[155]=-0,001597881
C[156]=-0,001766682	C[157]=-0,001937389	C[158]=-0,002110004	C[159]=-0,002283096
C[160]=-0,002457142	C[161]=-0,002630711	C[162]=-0,002803326	C[163]=-0,002974033
C[164]=-0,003141880	C[165]=-0,003306866	C[166]=-0,003467083	C[167]=-0,003622532
C[168]=-0,003771782	C[169]=-0,003914356	C[170]=-0,004048824	C[171]=-0,004174709
C[172]=-0,004290581	C[173]=-0,004395962	C[174]=-0,004489899	C[175]=-0,004570484
C[176]=-0,004638195	C[177]=-0,004691124	C[178]=-0,004728317	C[179]=-0,004748821
C[180]=-0,004752159	C[181]=-0,004737377	C[182]=-0,004703045	C[183]=-0,004649162
C[184]=-0,004573822	C[185]=-0,004477024	C[186]=-0,004357815	C[187]=-0,004215240
C[188]=-0,004049301	C[189]=-0,003858566	C[190]=-0,003643036	C[191]=-0,003401756
C[192]= 0,003134727	C[193]= 0,002841473	C[194]= 0,002521515	C[195]= 0,002174854
C[196]= 0,001800537	C[197]= 0,001399517	C[198]= 0,000971317	C[199]= 0,000515938
C[200]= 0,000033379	C[201]=-0,000475883	C[202]=-0,001011848	C[203]=-0,001573563
C[204]=-0,002161503	C[205]=-0,002774239	C[206]=-0,003411293	C[207]=-0,004072189
C[208]=-0,004756451	C[209]=-0,005462170	C[210]=-0,006189346	C[211]=-0,006937027
C[212]=-0,007703304	C[213]=-0,008487225	C[214]=-0,009287834	C[215]=-0,010103703
C[216]=-0,010933399	C[217]=-0,011775017	C[218]=-0,012627602	C[219]=-0,013489246
C[220]=-0,014358521	C[221]=-0,015233517	C[222]=-0,016112804	C[223]=-0,016994476
C[224]=-0,017876148	C[225]=-0,018756866	C[226]=-0,019634247	C[227]=-0,020506859
C[228]=-0,021372318	C[229]=-0,022228718	C[230]=-0,023074150	C[231]=-0,023907185
C[232]=-0,024725437	C[233]=-0,025527000	C[234]=-0,026310921	C[235]=-0,027073860
C[236]=-0,027815342	C[237]=-0,028532982	C[238]=-0,029224873	C[239]=-0,029890060
C[240]=-0,030526638	C[241]=-0,031132698	C[242]=-0,031706810	C[243]=-0,032248020
C[244]=-0,032754898	C[245]=-0,033225536	C[246]=-0,033659935	C[247]=-0,034055710

C[248]= -0,034412861	C[249]= -0,034730434	C[250]= -0,035007000	C[251]= -0,035242081
C[252]= -0,035435200	C[253]= -0,035586357	C[254]= -0,035694122	C[255]= -0,035758972
C[256]= 0,035780907	C[257]= 0,035758972	C[258]= 0,035694122	C[259]= 0,035586357
C[260]= 0,035435200	C[261]= 0,035242081	C[262]= 0,035007000	C[263]= 0,034730434
C[264]= 0,034412861	C[265]= 0,034055710	C[266]= 0,033659935	C[267]= 0,033225536
C[268]= 0,032754898	C[269]= 0,032248020	C[270]= 0,031706810	C[271]= 0,031132698
C[272]= 0,030526638	C[273]= 0,029890060	C[274]= 0,029224873	C[275]= 0,028532982
C[276]= 0,027815342	C[277]= 0,027073860	C[278]= 0,026310921	C[279]= 0,025527000
C[280]= 0,024725437	C[281]= 0,023907185	C[282]= 0,023074150	C[283]= 0,022228718
C[284]= 0,021372318	C[285]= 0,020506859	C[286]= 0,019634247	C[287]= 0,018756866
C[288]= 0,017876148	C[289]= 0,016994476	C[290]= 0,016112804	C[291]= 0,015233517
C[292]= 0,014358521	C[293]= 0,013489246	C[294]= 0,012627602	C[295]= 0,011775017
C[296]= 0,010933399	C[297]= 0,010103703	C[298]= 0,009287834	C[299]= 0,008487225
C[300]= 0,007703304	C[301]= 0,006937027	C[302]= 0,006189346	C[303]= 0,005462170
C[304]= 0,004756451	C[305]= 0,004072189	C[306]= 0,003411293	C[307]= 0,002774239
C[308]= 0,002161503	C[309]= 0,001573563	C[310]= 0,001011848	C[311]= 0,000475883
C[312]= -0,000033379	C[313]= -0,000515938	C[314]= -0,000971317	C[315]= -0,001399517
C[316]= -0,001800537	C[317]= -0,002174854	C[318]= -0,002521515	C[319]= -0,002841473
C[320]= 0,003134727	C[321]= 0,003401756	C[322]= 0,003643036	C[323]= 0,003858566
C[324]= 0,004049301	C[325]= 0,004215240	C[326]= 0,004357815	C[327]= 0,004477024
C[328]= 0,004573822	C[329]= 0,004649162	C[330]= 0,004703045	C[331]= 0,004737377
C[332]= 0,004752159	C[333]= 0,004748821	C[334]= 0,004728317	C[335]= 0,004691124
C[336]= 0,004638195	C[337]= 0,004570484	C[338]= 0,004489899	C[339]= 0,004395962
C[340]= 0,004290581	C[341]= 0,004174709	C[342]= 0,004048824	C[343]= 0,003914356
C[344]= 0,003771782	C[345]= 0,003622532	C[346]= 0,003467083	C[347]= 0,003306866
C[348]= 0,003141880	C[349]= 0,002974033	C[350]= 0,002803326	C[351]= 0,002630711
C[352]= 0,002457142	C[353]= 0,002283096	C[354]= 0,002110004	C[355]= 0,001937389
C[356]= 0,001766682	C[357]= 0,001597881	C[358]= 0,001432419	C[359]= 0,001269817
C[360]= 0,001111031	C[361]= 0,000956535	C[362]= 0,000806808	C[363]= 0,000661850
C[364]= 0,000522137	C[365]= 0,000388145	C[366]= 0,000259876	C[367]= 0,000137329
C[368]= 0,000021458	C[369]= -0,000088215	C[370]= -0,000191689	C[371]= -0,000288486
C[372]= -0,000378609	C[373]= -0,000462532	C[374]= -0,000539303	C[375]= -0,000610352
C[376]= -0,000674248	C[377]= -0,000731945	C[378]= -0,000783920	C[379]= -0,000829220
C[380]= -0,000868797	C[381]= -0,000902653	C[382]= -0,000930786	C[383]= -0,000953674
C[384]= 0,000971317	C[385]= 0,000983715	C[386]= 0,000991821	C[387]= 0,000995159
C[388]= 0,000994205	C[389]= 0,000989437	C[390]= 0,000980854	C[391]= 0,000968933
C[392]= 0,000954151	C[393]= 0,000935555	C[394]= 0,000915051	C[395]= 0,000891685
C[396]= 0,000866413	C[397]= 0,000838757	C[398]= 0,000809669	C[399]= 0,000779152
C[400]= 0,000747204	C[401]= 0,000714302	C[402]= 0,000680923	C[403]= 0,000646591
C[404]= 0,000611782	C[405]= 0,000576973	C[406]= 0,000542164	C[407]= 0,000507355
C[408]= 0,000472546	C[409]= 0,000438213	C[410]= 0,000404358	C[411]= 0,000371456
C[412]= 0,000339031	C[413]= 0,000307560	C[414]= 0,000277042	C[415]= 0,000247478
C[416]= 0,000218868	C[417]= 0,000191212	C[418]= 0,000165462	C[419]= 0,000140190
C[420]= 0,000116348	C[421]= 0,000093937	C[422]= 0,000072956	C[423]= 0,000052929
C[424]= 0,000034332	C[425]= 0,000017166	C[426]= 0,000000954	C[427]= -0,000013828
C[428]= -0,000027180	C[429]= -0,000039577	C[430]= -0,000050545	C[431]= -0,000060558
C[432]= -0,000069618	C[433]= -0,000077724	C[434]= -0,000084400	C[435]= -0,000090122
C[436]= -0,000095367	C[437]= -0,000099182	C[438]= -0,000102520	C[439]= -0,000105381
C[440]= -0,000106812	C[441]= -0,000108242	C[442]= -0,000108719	C[443]= -0,000108719
C[444]= -0,000108242	C[445]= -0,000107288	C[446]= -0,000105858	C[447]= -0,000103951
C[448]= 0,000101566	C[449]= 0,000099182	C[450]= 0,000096321	C[451]= 0,000093460
C[452]= 0,000090599	C[453]= 0,000087261	C[454]= 0,000083923	C[455]= 0,000080585
C[456]= 0,000076771	C[457]= 0,000073433	C[458]= 0,000070095	C[459]= 0,000066280
C[460]= 0,000062943	C[461]= 0,000059605	C[462]= 0,000055790	C[463]= 0,000052929
C[464]= 0,000049591	C[465]= 0,000046253	C[466]= 0,000043392	C[467]= 0,000040531
C[468]= 0,000037670	C[469]= 0,000034809	C[470]= 0,000032425	C[471]= 0,000030041
C[472]= 0,000027657	C[473]= 0,000025272	C[474]= 0,000023365	C[475]= 0,000021458
C[476]= 0,000019550	C[477]= 0,000018120	C[478]= 0,000016689	C[479]= 0,000014782
C[480]= 0,000013828	C[481]= 0,000012398	C[482]= 0,000011444	C[483]= 0,000010014
C[484]= 0,000009060	C[485]= 0,000008106	C[486]= 0,000007629	C[487]= 0,000006676
C[488]= 0,000006199	C[489]= 0,000005245	C[490]= 0,000004768	C[491]= 0,000004292
C[492]= 0,000003815	C[493]= 0,000003338	C[494]= 0,000003338	C[495]= 0,000002861
C[496]= 0,000002384	C[497]= 0,000002384	C[498]= 0,000001907	C[499]= 0,000001907
C[500]= 0,000001431	C[501]= 0,000001431	C[502]= 0,000000954	C[503]= 0,000000954

C[504]= 0,000000954	C[505]= 0,000000954	C[506]= 0,000000477	C[507]= 0,000000477
C[508]= 0,000000477	C[509]= 0,000000477	C[510]= 0,000000477	C[511]= 0,000000477

C.2 Psychoacoustic model

For each frame, corresponding to 1 152 input samples, with a duration of 24 ms at a sampling frequency (f_s) of 48 kHz or 48 ms at a sampling frequency (f_s) of 24 kHz, a bit allocation shall be determined. The bit allocation of the 32 sub-bands should be calculated on the basis of the signal-to-mask ratios of all the sub-bands. Therefore it is necessary to determine, for each sub-band the maximum signal level and the minimum masking threshold in dB. The minimum masking threshold is derived from an Fast Fourier Transform (FFT) of the input PCM signal, followed by a psychoacoustic model calculation.

The FFT in parallel with the sub-band filter compensates for the lack of spectral selectivity obtained at low frequencies by the sub-band filter bank. This technique provides both a sufficient time resolution for the coded audio signal (Polyphase filter with optimized window for minimal pre-echoes) and a sufficient spectral resolution for the calculation of the masking thresholds.

The frequencies and levels of aliasing distortions can be calculated. This is necessary for calculating a minimum bit rate for those sub-bands which need some bits to cancel the aliasing components in the decoder. The additional complexity to calculate the better frequency resolution is necessary only in the encoder, and introduces no additional delay or complexity in the decoder.

The calculation of the signal-to-mask-ratio (SMR) is based on the following steps:

- Step 1:** calculation of the FFT for time to frequency conversion;
- Step 2:** determination of the sound pressure level in dB in each sub-band;
- Step 3:** determination of the threshold in quiet (absolute threshold);
- Step 4:** finding of the tonal (more sinusoid-like) and non-tonal (more noise-like) components of the audio signal;
- Step 5:** decimation of the maskers, to obtain only the relevant maskers;
- Step 6:** calculation of the individual masking thresholds;
- Step 7:** determination of the global masking threshold;
- Step 8:** determination of the minimum masking threshold in each sub-band;
- Step 9:** calculation of the signal-to-mask ratio in each sub-band.

The following gives further details on the above steps.

- Step 1:** FFT Analysis.

The masking threshold is derived from an estimate of the power density spectrum that is calculated by a 1 024-point FFT. The FFT is calculated directly from the input PCM signal, windowed by a Hann window.

For a coincidence in time between the bit allocation and the corresponding sub-band samples, the PCM-samples entering the FFT have to be delayed:

- 1) the delay of the analysis sub-band filter is 256 samples, corresponding to 5,3 ms at 48 kHz sampling frequency (i.e. $f_s = 48$ kHz), or 10,67 ms at 24 kHz sampling frequency (i.e. $f_s = 24$ kHz). A window shift of 256 samples is required to compensate for the delay in the analysis sub-band filter;
- 2) the Hann window shall coincide with the sub-band samples of the frame. This requires an additional window shift of minus 64 samples.

Technical data of the FFT:

- transform length N : 1 024 samples;
- Window size: 21,3 ms for $f_s = 48$ kHz, or 42,67 ms for $f_s = 24$ kHz;
- Frequency resolution: 46,875 Hz for $f_s = 48$ kHz, or 23,438 Hz for $f_s = 24$ kHz;
- Hann window, $h(i)$: $h(i) = \sqrt{8/3} \times 0,5 \times \{1 - \cos[2 \times \pi \times i/N]\}$ $0 \leq i \leq N-1$;
- power density spectrum $X(k)$:

$$X(k) = 10 \times \log_{10} \left| \frac{1}{N} \sum_{l=0}^{N-1} h(l) \times s(l) \times e^{(j \times k \times l \times 2 \times \pi N)} \right|^2 \text{ dB} \quad 0 \leq k \leq N/2$$

where $s(l)$ is the input signal.

A normalization to the reference level of 96 dB SPL (Sound Pressure Level) should be done in such a way that the maximum value corresponds to 96 dB.

Step 2: Determination of the Sound Pressure Level.

The SPL L_{sb} in sub-band n should be computed by:

$$L_{sb}(n) = \text{MAX}[X(k), 20 \times \log_{10}(\text{scf}_{\text{max}}(n) \times 32\,768) - 10] \text{ dB}$$

$X(k)$ in sub-band n

where $X(k)$ is the Sound Pressure Level of the spectral line with index k of the FFT with the maximum amplitude in the frequency range corresponding to sub-band n . The expression $\text{scf}_{\text{max}}(n)$ is the maximum of the three Scale Factors of sub-band n within a frame. The "-10 dB" term corrects for the difference between peak and rms level. The Sound Pressure Level $L_{sb}(n)$ is computed for every sub-band n .

The following alternative method of calculating $L_{sb}(n)$ offers a potential for better encoder performance, but this technique has not been subjected to a formal audio quality test.

The alternative SPL $L_{sb}(n)$ in sub-band n should be computed by:

$$L_{sb}(n) = \text{MAX}[X_{\text{spl}}(n), 20 \times \log_{10}(\text{scf}_{\text{max}}(n) \times 32\,768) - 10] \text{ dB};$$

with,

$$X_{\text{spl}}(n) = 10 \log \left(\sum_{k(n)}^{k(n+1)} 10^{X(k)/10} \right) \text{ dB},$$

where $k(n) = n \times N/64$

and $X_{\text{spl}}(n)$ is the alternative Sound Pressure Level corresponding to sub-band n .

Step 3: Considering the threshold in quiet.

The threshold in quiet $LT_q(k)$, also called absolute threshold, is available in the table C.2 for the sampling frequency of 48 kHz and in the table C.3 for the sampling frequency of 24 kHz. Values are available for each sample in the frequency domain where the masking threshold is calculated.

An offset depending on the overall bit rate should be used for the absolute threshold. This offset is -12 dB for bit rates ≥ 96 kbit/s and 0 dB for bit rates < 96 kbit/s per channel.

Step 4: Finding of tonal and non-tonal components.

The tonality of a masking component has an influence on the masking threshold. For this reason, it is worthwhile to discriminate between tonal and non-tonal components. For calculating the global masking threshold it is necessary to derive the tonal and the non-tonal components from the FFT spectrum.

This step should start with the determination of local maxima, continued by extracting tonal components (sinusoids) and calculating the intensity of the non-tonal components within a bandwidth of a Critical band. The boundaries of the Critical bands are given in the table C.4 for 48 kHz sampling frequency and in the table C.5 for 24 kHz sampling frequency.

The bandwidth of the Critical bands varies with the centre frequency with a bandwidth of about only 0,1 kHz at low frequencies and with a bandwidth of about 4 kHz at high frequencies. It is known from psychoacoustic experiments that the ear has a better frequency resolution in the lower than in the higher frequency region. To determine if a local maximum may be a tonal component a frequency range df around the local maximum should be examined. For $f_s = 48$ kHz, the frequency range df is given by:

$$df = 93,75 \text{ Hz} \quad 0,0 \text{ kHz} < f \leq 3,0 \text{ kHz};$$

$$df = 140,63 \text{ Hz} \quad 3,0 \text{ kHz} < f \leq 6,0 \text{ kHz};$$

$$df = 281,25 \text{ Hz} \quad 6,0 \text{ kHz} < f \leq 12,0 \text{ kHz};$$

$$df = 562,50 \text{ Hz} \quad 12,0 \text{ kHz} < f \leq 24,0 \text{ kHz}.$$

For $f_s = 24$ kHz sampling frequency, the frequency range df is given by:

$$df = 93,75 \text{ Hz} \quad 0,0 \text{ kHz} < f \leq 3,0 \text{ kHz};$$

$$df = 140,63 \text{ Hz} \quad 3,0 \text{ kHz} < f \leq 6,0 \text{ kHz};$$

$$df = 281,25 \text{ Hz} \quad 6,0 \text{ kHz} < f \leq 11,25 \text{ kHz}.$$

To make lists of the spectral lines $X(k)$ that are tonal or non-tonal, the following three operations are performed:

a) Labelling of local maxima:

- a spectral line $X(k)$ is labelled as a local maximum if:

$$X(k) > X(k-1) \quad \text{and} \quad X(k) \geq X(k+1).$$

b) Listing of tonal components and calculation of the Sound Pressure Level:

- a local maximum is put in the list of tonal components if:

$$X(k) - X(k+j) \geq 7 \text{ dB},$$

where j is chosen according to:

$$j = -2, +2 \quad \text{for } 2 < k < 63 \quad \text{and } f_s = 48 \text{ kHz};$$

$$j = -3, -2, +2, +3 \quad \text{for } 63 \leq k < 127 \quad \text{and } f_s = 48 \text{ kHz};$$

$$j = -4, +4 \quad \text{for } 4 < k < 127 \quad \text{and } f_s = 24 \text{ kHz};$$

$$j = -6, \dots, -2, +2, \dots, +6 \quad \text{for } 127 \leq k < 255 \quad \text{and } f_s = 48 \text{ kHz or } 24 \text{ kHz};$$

$$j = -12, \dots, -2, +2, \dots, +12 \quad \text{for } 255 \leq k \leq 500 \quad \text{and } f_s = 48 \text{ kHz or } 24 \text{ kHz}.$$

If $X(k)$ is found to be a tonal component, then the following parameters are listed:

- index number k of the spectral line;
- $\text{SPL } X_{tm}(k) = 10 \times \log_{10} (10^{X(k-1)/10} + 10^{X(k)/10} + 10^{X(k+1)/10}) \text{ dB};$

- tonal flag.

Next, all spectral lines within the examined frequency range are set to $-\infty$ dB.

c) Listing of non-tonal components and calculation of the power:

The non-tonal (noise) components are calculated from the remaining spectral lines. To calculate the non-tonal components from these spectral lines $X(k)$, the Critical bands $z(k)$ are determined using the table C.4 in the case of 48 kHz sampling frequency coding and table C.5 in the case of 24 kHz sampling frequency coding. For 48 kHz sampling frequency 27 Critical bands are considered (see table C.4). For 24 kHz sampling frequency, 23 Critical bands are considered (see table C.5). Within each Critical band, the power of the spectral lines (remained after the tonal components have been zeroed) are summed to form the Sound Pressure Level of the new non-tonal component $X_{nm}(k)$ corresponding to that Critical band.

The following parameters are listed:

- index number k of the spectral line nearest to the geometric mean of the Critical band;
- SPL $X_{nm}(k)$ in dB;
- non-tonal flag.

Step 5: Decimation of tonal and non-tonal masking components.

Decimation is a procedure that is used to reduce the number of maskers which are considered for the calculation of the global masking threshold:

- a) Tonal $X_{tm}(k)$ or non-tonal components $X_{nm}(k)$ are considered for the calculation of the masking threshold only if:

$$X_{tm}(k) \geq LT_q(k) \quad \text{or} \quad X_{nm}(k) \geq LT_q(k).$$

In this expression, $LT_q(k)$ is the absolute threshold (or threshold in quiet) at the frequency of index k . These values are given in table C.2 for 48 kHz sampling frequency coding and in table C.3 for 24 kHz sampling frequency coding.

- b) Decimation of two or more tonal components within a distance of less than 0,5 Bark. The component with the highest power should be kept, and the smaller component(s) should be removed from the list of tonal components. For this operation, a sliding window in the Critical band domain should be used with a width of 0,5 Bark.

In the following, the index j is used to indicate the relevant tonal or non-tonal masking components from the combined decimated list.

Step 6: Calculation of individual masking thresholds.

Of the original 512 frequency domain samples, indexed by k , only a subset of the samples, indexed by i , are considered for the global masking threshold calculation. The samples used are shown in tables C.2 and C.3.

For the frequency lines corresponding to the frequency region which is covered by the first three sub-bands no sub-sampling is used. For the frequency region which is covered by next three sub-bands every second spectral line is considered. For the frequency region corresponding to the next six sub-bands every fourth spectral line is considered. With a sampling frequency of 48 kHz, in the remaining sub-bands every eighth spectral line is considered up to 20 kHz (see also table C.2). With a sampling frequency of 24 kHz, every eighth spectral line is considered for the next 18 sub-bands (see also table C.3). The number of samples, i , in the subsampled frequency domain is 126 with a sampling frequency of 48 kHz, and 132 with a sampling frequency of 24 kHz.

Every tonal and non-tonal component is assigned the value of the index i which most closely corresponds to the frequency of the original spectral line $X(k)$. This index i is given in tables C.2 and C.3.

The individual masking thresholds of both tonal and non-tonal components are given by the following expression:

$$LT_{tm}[z(j),z(i)] = X_{tm}[z(j)] + av_{tm}[z(j)] + vf[z(j),z(i)] \quad \text{dB};$$

$$LT_{nm}[z(j),z(i)] = X_{nm}[z(j)] + av_{nm}[z(j)] + vf[z(j),z(i)] \quad \text{dB}.$$

In this formula LT_{tm} and LT_{nm} are the individual masking thresholds at Critical band rate z in Bark of the masking component at the Critical band rate z_m in Bark. The values in dB can be either positive or negative. The term $X_{tm}[z(j)]$ is the Sound Pressure Level of the masking component with the index number j at the corresponding Critical band rate $z(j)$. The term av is called the masking index and vf the masking function of the masking component $X_{tm}[z(j)]$. The masking index av is different for tonal and non-tonal masker (av_{tm} and av_{nm}).

For tonal maskers it is given by:

$$av_{tm} = -1,525 - 0,275 \times z(j) - 4,5 \text{ dB},$$

and for non-tonal maskers:

$$av_{nm} = -1,525 - 0,175 \times z(j) - 0,5 \text{ dB}.$$

The masking function vf of a masker is characterized by different lower and upper slopes, which depend on the distance in Bark $dz = z(i) - z(j)$ to the masker. In this expression i is the index of the spectral line at which the masking function is calculated and j that of the masker. The Critical band rates $z(j)$ and $z(i)$ can be found in tables C.2 and C.3. The masking function, which is the same for tonal and non-tonal maskers, is given by:

$$\begin{aligned} vf &= 17 \times (dz + 1) - (0,4 \times X[z(j)] + 6) \text{ dB} && \text{for } -3 \leq dz < -1 \text{ Bark;} \\ vf &= (0,4 \times X[z(j)] + 6) \times dz \text{ dB} && \text{for } -1 \leq dz < 0 \text{ Bark;} \\ vf &= -17 \times dz \text{ dB} && \text{for } 0 \leq dz < 1 \text{ Bark;} \\ vf &= -(dz - 1) \times (17 - 0,15 \times X[z(j)]) - 17 \text{ dB} && \text{for } 1 \leq dz < 8 \text{ Bark.} \end{aligned}$$

In these expressions $X[z(j)]$ is the Sound Pressure Level of the j 'th masking component in dB. For reasons of implementation complexity, the masking should no longer be considered (LT_{tm} and LT_{nm} are set to $-\infty$ dB outside this range) if $dz < -3$ Bark, or $dz \geq 8$ Bark.

Step 7: Calculation of the global masking threshold LT_g .

The global masking threshold $LT_g(i)$ at the i 'th frequency sample is derived from the upper and lower slopes of the individual masking threshold of each of the j tonal and non-tonal maskers, and in addition from the threshold in quiet $LT_q(i)$, which is also given in tables C.2 and C.3. The global masking threshold is found by summing the powers corresponding to the individual masking thresholds and the threshold in quiet.

$$LT_g(i) = 10 \log_{10} \left(10^{LT_q(i)/10} + \sum_{j=1}^m 10^{LT_{tm}[z(j), z(i)]/10} + \sum_{j=1}^n 10^{LT_{nm}[z(j), z(i)]/10} \right) \text{ dB}$$

The total number of tonal maskers is given by m , and the total number of non-tonal maskers is given by n . For a given i , the range of j can be reduced to just encompass those masking components that are within -8 to +3 Bark from i . Outside of this range LT_{tm} and LT_{nm} are $-\infty$ dB.

Step 8: Determination of the minimum masking threshold.

The minimum masking level $LT_{min}(n)$ in sub-band n is determined by the following expression:

$$LT_{min}(n) = \text{MIN}[LT_g(i)] \text{ dB}$$

$f(i)$ in sub-band n

where $f(i)$ is the frequency of the i 'th frequency sample. The $f(i)$ are tabulated in the tables C.2 and C.3.

A minimum masking level $LT_{min}(n)$ is computed for every sub-band.

Step 9: Calculation of the Signal-to-Mask-Ratio.

The Signal-to-Mask Ratio

$$SMR_{sb(n)} = L_{sb(n)} - LT_{min(n)} \text{ dB}$$

is computed for every sub-band n .**Table C.2: Frequencies, critical band rates and absolute threshold for a sampling frequency of 48 kHz**

Index number <i>i</i>	Frequency Hz	Critical band rate <i>z</i>	Absolute threshold dB	Index number <i>i</i>	Frequency Hz	Critical band rate <i>z</i>	Absolute threshold dB
1	46,88	0,463	42,10	39	1 828,13	12,518	0,49
2	93,75	0,925	24,17	40	1 875,00	12,684	0,29
3	140,63	1,385	17,47	41	1 921,88	12,845	0,09
4	187,50	1,842	13,87	42	1 968,75	13,002	-0,11
5	234,38	2,295	11,60	43	2 015,63	13,154	-0,32
6	281,25	2,742	10,01	44	2 062,50	13,302	-0,54
7	328,13	3,184	8,84	45	2 109,38	13,446	-0,75
8	375,00	3,618	7,94	46	2 156,25	13,586	-0,97
9	421,88	4,045	7,22	47	2 203,13	13,723	-1,20
10	468,75	4,463	6,62	48	2 250,00	13,855	-1,43
11	515,63	4,872	6,12	49	2 343,75	14,111	-1,88
12	562,50	5,272	5,70	50	2 437,50	14,354	-2,34
13	609,38	5,661	5,33	51	2 531,25	14,585	-2,79
14	656,25	6,041	5,00	52	2 625,00	14,807	-3,22
15	703,13	6,411	4,71	53	2 718,75	15,018	-3,62
16	750,00	6,770	4,45	54	2 812,50	15,221	-3,98
17	796,88	7,119	4,21	55	2 906,25	15,415	-4,30
18	843,75	7,457	4,00	56	3 000,00	15,602	-4,57
19	890,63	7,785	3,79	57	3 093,75	15,783	-4,77
20	937,50	8,103	3,61	58	3 187,50	15,956	-4,91
21	984,38	8,410	3,43	59	3 281,25	16,124	-4,98
22	1 031,25	8,708	3,26	60	3 375,00	16,287	-4,97
23	1 078,13	8,996	3,09	61	3 468,75	16,445	-4,90
24	1 125,00	9,275	2,93	62	3 562,50	16,598	-4,76
25	1 171,88	9,544	2,78	63	3 656,25	16,746	-4,55
26	1 218,75	9,805	2,63	64	3 750,00	16,891	-4,29
27	1 265,63	10,057	2,47	65	3 843,75	17,032	-3,99
28	1 312,50	10,301	2,32	66	3 937,50	17,169	-3,64
29	1 359,38	10,537	2,17	67	4 031,25	17,303	-3,26
30	1 406,25	10,765	2,02	68	4 125,00	17,434	-2,86
31	1 453,13	10,986	1,86	69	4 218,75	17,563	-2,45
32	1 500,00	11,199	1,71	70	4 312,50	17,688	-2,04
33	1 546,88	11,406	1,55	71	4 406,25	17,811	-1,63
34	1 593,75	11,606	1,38	72	4 500,00	17,932	-1,24
35	1 640,63	11,800	1,21	73	4 687,50	18,166	-0,51
36	1 687,50	11,988	1,04	74	4 875,00	18,392	0,12
37	1 734,38	12,170	0,86	75	5 062,50	18,611	0,64
38	1 781,25	12,347	0,67	76	5 250,00	18,823	1,06
77	5 437,50	19,028	1,39	102	11 250,00	22,941	16,54
78	5 625,00	19,226	1,66	103	11 625,00	23,072	18,77
79	5 812,50	19,419	1,88	104	12 000,00	23,195	21,23
80	6 000,00	19,606	2,08	105	12 375,00	23,309	23,94
81	6 187,50	19,788	2,27	106	12 750,00	23,415	26,90
82	6 375,00	19,964	2,46	107	13 125,00	23,515	30,14
83	6 562,50	20,135	2,65	108	13 500,00	23,607	33,67
84	6 750,00	20,300	2,86	109	13 875,00	23,694	37,51
85	6 937,50	20,461	3,09	110	14 250,00	23,775	41,67
86	7 125,00	20,616	3,33	111	14 625,00	23,852	46,17
87	7 312,50	20,766	3,60	112	15 000,00	23,923	51,04
88	7 500,00	20,912	3,89	113	15 375,00	23,991	56,29
89	7 687,50	21,052	4,20	114	15 750,00	24,054	61,94
90	7 875,00	21,188	4,54	115	16 125,00	24,114	68,00
91	8 062,50	21,318	4,91	116	16 500,00	24,171	68,00
92	8 250,00	21,445	5,31	117	16 875,00	24,224	68,00
93	8 437,50	21,567	5,73	118	17 250,00	24,275	68,00

Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB	Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB
94	8 625,00	21,684	6,18	119	17 625,00	24,322	68,00
95	8 812,50	21,797	6,67	120	18 000,00	24,368	68,00
96	9 000,00	21,906	7,19	121	18 375,00	24,411	68,00
97	9 375,00	22,113	8,33	122	18 750,00	24,452	68,00
98	9 750,00	22,304	9,63	123	19 125,00	24,491	68,00
99	10 125,00	22,482	11,08	124	19 500,00	24,528	68,00
100	10 500,00	22,646	12,71	125	19 875,00	24,564	68,00
101	10 875,00	22,799	14,53	126	20 250,00	24,597	68,00

Table C.3: Frequencies, critical band rates and absolute threshold for a sampling frequency of 24 kHz

Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB	Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB
1	23,44	0,232	68,00	39	914,06	7,945	3,70
2	46,88	0,463	42,10	40	937,50	8,103	3,61
3	70,31	0,694	30,43	41	960,94	8,258	3,51
4	93,75	0,925	24,17	42	984,38	8,410	3,43
5	117,19	1,156	20,22	43	1 007,81	8,560	3,34
6	140,63	1,385	17,47	44	1 031,25	8,708	3,26
7	164,06	1,614	15,44	45	1 054,69	8,853	3,17
8	187,50	1,842	13,87	46	1 078,13	8,996	3,09
9	210,94	2,069	12,62	47	1 101,56	9,137	3,01
10	234,38	2,295	11,60	48	1 125,00	9,275	2,93
11	257,81	2,519	10,74	49	1 171,88	9,544	2,78
12	281,25	2,742	10,01	50	1 218,75	9,805	2,63
13	304,69	2,964	9,39	51	1 265,63	10,057	2,47
14	328,13	3,184	8,84	52	1 312,50	10,301	2,32
15	351,56	3,402	8,37	53	1 359,38	10,537	2,17
16	375,00	3,618	7,94	54	1 406,25	10,765	2,02
17	398,44	3,832	7,56	55	1 453,13	10,986	1,86
18	421,88	4,045	7,22	56	1 500,00	11,199	1,71
19	445,31	4,255	6,90	57	1 546,88	11,406	1,55
20	468,75	4,463	6,62	58	1 593,75	11,606	1,38
21	492,19	4,668	6,36	59	1 640,63	11,800	1,21
22	515,63	4,872	6,12	60	1 687,50	11,988	1,04
23	539,06	5,073	5,90	61	1 734,38	12,170	0,86
24	562,50	5,272	5,70	62	1 781,25	12,347	0,67
25	585,94	5,468	5,50	63	1 828,13	12,518	0,49
26	609,38	5,661	5,33	64	1 875,00	12,684	0,29
27	632,81	5,853	5,16	65	1 921,88	12,845	0,09
28	656,25	6,041	5,00	66	1 968,75	13,002	-0,11
29	679,69	6,227	4,85	67	2 015,63	13,154	-0,32
30	703,13	6,411	4,71	68	2 062,50	13,302	-0,54
31	726,56	6,592	4,58	69	2 109,38	13,446	-0,75
32	750,00	6,770	4,45	70	2 156,25	13,586	-0,97
33	773,44	6,946	4,33	71	2 203,13	13,723	-1,20
34	796,88	7,119	4,21	72	2 250,00	13,855	-1,43
35	820,31	7,289	4,10	73	2 343,75	14,111	-1,88
36	843,75	7,457	4,00	74	2 437,50	14,354	-2,34
37	867,19	7,622	3,89	75	2 531,25	14,585	-2,79
38	890,63	7,785	3,79	76	2 625,00	14,807	-3,22
77	2 718,75	15,018	-3,62	105	6 187,50	19,788	2,25
78	2 812,50	15,221	-3,98	106	6 375,00	19,964	2,43
79	2 906,25	15,415	-4,30	107	6 562,50	20,135	2,63
80	3 000,00	15,602	-4,57	108	6 750,00	20,300	2,83
81	3 093,75	15,783	-4,77	109	6 937,50	20,461	3,06
82	3 187,50	15,956	-4,91	110	7 125,00	20,616	3,30
83	3 281,25	16,124	-4,98	111	7 312,50	20,766	3,57
84	3 375,00	16,287	-4,98	112	7 500,00	20,912	3,85
85	3 468,75	16,445	-4,92	113	7 687,50	21,052	4,16
86	3 562,50	16,598	-4,80	114	7 875,00	21,188	4,50
87	3 656,25	16,746	-4,61	115	8 062,50	21,318	4,86
88	3 750,00	16,891	-4,36	116	8 250,00	21,445	5,25

Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB	Index number i	Frequency Hz	Critical band rate z	Absolute threshold dB
89	3 843,75	17,032	-4,07	117	8 437,50	21,567	5,67
90	3 937,50	17,169	-3,73	118	8 625,00	21,684	6,12
91	4 031,25	17,303	-3,36	119	8 812,50	21,797	6,61
92	4 125,00	17,434	-2,96	120	9 000,00	21,906	7,12
93	4 218,75	17,563	-2,55	121	9 187,50	22,012	7,67
94	4 312,50	17,688	-2,14	122	9 375,00	22,113	8,26
95	4 406,25	17,811	-1,73	123	9 562,50	22,210	8,88
96	4 500,00	17,932	-1,33	124	9 750,00	22,304	9,54
97	4 687,50	18,166	-0,59	125	9 937,50	22,395	10,24
98	4 875,00	18,392	0,05	126	10 125,00	22,482	10,98
99	5 062,50	18,611	0,58	127	10 312,50	22,566	11,77
100	5 250,00	18,823	1,01	128	10 500,00	22,646	12,60
101	5 437,50	19,028	1,36	129	10 687,50	22,724	13,48
102	5 625,00	19,226	1,63	130	10 875,00	22,799	14,41
103	5 812,50	19,419	1,86	131	11 062,50	22,871	15,38
104	6 000,00	19,606	2,06	132	11 250,00	22,941	16,41

C.3 Bit allocation procedure

Before adjustment to a fixed bit rate, the number of bits, "*adb*", that are available for coding the sub-band samples and the Scale Factors shall be determined. This number can be obtained by subtracting from the total number of available bits "*cb*", the number of bits needed for bit allocation "*bbal*", and the number of bits "*banc*" required for ancillary data:

$$adb = cb - (bbal + banc)$$

The resulting number should be used to code the sub-band samples and the Scale Factors. The principle used in the allocation procedure is minimization of the total Noise-to-Mask Ratio over the DAB audio frame with the constraint that the number of bits used does not exceed the number of bits available for that frame. Use is made of tables 14 to 16, that indicate for every sub-band the number of steps that may be used to quantize the samples. The number of bits required to represent these quantized samples can be derived from table 17.

Table C.4: Critical band boundaries for a sampling frequency of 48 kHz

No.	Index of table F&CB	Frequency Hz	Bark z
0	1	46,875	0,463
1	2	93,750	0,925
2	3	140,625	1,385
3	5	234,375	2,295
4	7	328,125	3,184
5	9	421,875	4,045
6	12	562,500	5,272
7	14	656,250	6,041
8	17	796,875	7,119
9	20	937,500	8,103
10	24	1 125,000	9,275
11	27	1 265,625	10,057
12	32	1 500,000	11,199
13	37	1 734,375	12,170
14	42	1 968,750	13,002
15	49	2 343,750	14,111
16	53	2 718,750	15,018
17	59	3 281,250	16,124
18	65	3 843,750	17,032
19	73	4 687,500	18,166
20	77	5 437,500	19,028
21	82	6 375,000	19,964
22	89	7 687,500	21,052
23	97	9 375,000	22,113
24	103	11 625,000	23,072
25	113	15 375,000	23,991
26	126	20 250,000	24,597

NOTE: The frequencies represent the top end of each critical band.

Table C.5: Critical band boundaries for a sampling frequency of 24 kHz

No.	Index of table F&CB	Frequency Hz	Bark z
0	4	93,75	0,925
1	9	210,94	2,069
2	13	304,69	2,964
3	18	421,88	4,045
4	23	539,06	5,073
5	28	656,25	6,041
6	33	773,44	6,946
7	39	914,06	7,945
8	46	1 078,13	8,996
9	51	1 265,63	10,057
10	55	1 453,13	10,986
11	60	1 687,50	11,988
12	66	1 968,75	13,002
13	73	2 343,75	14,111
14	77	2 718,75	15,018
15	82	3 187,50	15,956
16	89	3 843,75	17,032
17	96	4 500,00	17,932
18	101	5 437,50	19,028
19	106	6 375,00	19,964
20	113	7 687,50	21,052
21	121	9 187,50	22,012
22	132	11 250,00	22,941

NOTE: The frequencies represent the top end of each critical band.

The allocation procedure is an iterative procedure where, in each iteration step the number of levels of the sub-band that has the greatest benefit is increased.

First the Mask-to-Noise Ratio "*MNR*" for each sub-band should be calculated by subtracting from the Signal-to-Noise-Ratio "*SNR*" the Signal-to-Mask-Ratio "*SMR*":

$$MNR = SNR - SMR$$

The *SNR* can be found in the informative table C.6. The *SMR* is the output of the psychoacoustic model.

Table C.6: Signal-to Noise-Ratios

No. of steps	SNR dB
0	0,00
3	7,00
5	11,00
7	16,00
9	20,84
15	25,28
31	31,59
63	37,75
127	43,84
255	49,89
511	55,93
1 023	61,96
2 047	67,98
4 095	74,01
8 191	80,03
16 383	86,05
32 767	92,01
65 535	98,01

Then zero bits should be allocated to the sub-band samples and the Scale Factors. The number of bits for the sub-band samples *bspl* and the number of bits for the Scale Factors *bscf* are set to zero. Next an iterative procedure should be started. Each iteration loop should contain the following steps:

- determination of the minimal *MNR* of all sub-bands;
- the accuracy of the quantization of the sub-band with the minimal *MNR* should be increased by using the next higher entry in the relevant tables 14 to 16;
- the new *MNR* of this sub-band should be calculated;
- *bspl* should be updated according to the additional number of bits required. If a non-zero number of bits is assigned to a sub-band for the first time, *bsel* has to be updated, and *bscf* has to be updated according to the number of Scale Factors required for this sub-band. Then *adb* should be calculated again using the formula:

$$adb = cb - (bbal + bsel + bscf + bspl + banc).$$

The iterative procedure should be repeated as long as *adb* is not less than any possible increase of *bspl*, *bsel* and *bscf* within one loop.

C.4 Bit sensitivity to errors

This part of the annex indicates the sensitivity of individual bits to random errors if application-specific error protection is needed. This sensitivity for each bit is given in table C.7 by a value from 0 to 5, indicating the amount of degradation resulting from one isolated error:

- 5 catastrophic;
- 4 very annoying;
- 3 annoying;
- 2 slightly annoying;
- 1 audible;
- 0 insensitive.

The values are not the results of precise measurements, rather they rely upon knowledge of the coding scheme. They assume that the error detection scheme is not in use. The DAB audio frame header and error check information defined in clauses 7.3.2.3 and 7.3.2.4 are considered to have the highest sensitivity.

Some fields in the DAB audio frame do not have a fixed length. All bits in this fields are rated for error sensitivity, even if not in use.

Table C.7: bit sensitivity of DAB audio frame bits

Parameters	Number of bits	Sensitivity
bit allocation	all bits	5
ScFSI	all bits	5
ScFs	5 (msb)	4
	4	4
	3	4
	2	3
	1	2
	0 (lsb)	1
sub-band samples (note)	8 -16(msb)	3
	5 - 7	2
	3,4	1
	(lsb)0 - 2	0
NOTE: according to the bit allocation.		

C.5 Error concealment

A feature of the coded bit stream is the CRC word which provides some error detection facility to the decoder, described in clause B.2. The Hamming distance of this error detection code is $d = 4$, which allows for the detection of up to 3 single bit errors or for the detection of one error burst of up to 16 bit length. The amount and the position of the protected bits within one encoded DAB audio frame generally depends on the mode and the bit rate.

The CRC word should be used to control an error concealment strategy in order to avoid severe impairments of the reconstructed audio signal due to errors in the most sensitive information.

Some basic techniques may be used for concealment, for instance information substitution, or muting. A simple substitution technique consists, when an erroneous frame occurs, of replacing it by the previous one (if error free).

In addition to the error protection facilities provided by the MPEG-1 and MPEG-2 Audio Layer II (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) audio coding standards, facilities for an error check of the Scale Factors have been provided in an ISO compatible manner. The exact method is described in clause B.3. To avoid audible distortions, evoked by erroneous Scale Factors, the application of a concealment technique, either muting of those Scale Factors where an error was detected, as a rather simple method, or a repetition of the previously received Scale Factors, which did not show an error in the 3 MSBs, as a more advanced method, is recommended.

C.6 Joint stereo coding

The optional joint stereo coding method used is intensity stereo coding. Intensity stereo coding can be used to increase the audio quality and/or reduce the bit rate for stereophonic signals. The gain in bit rate is typically about 10 kbit/s to 30 kbit/s. It requires negligible additional decoder complexity. The increase of encoder complexity is small. The encoder and decoder delay is not affected.

Psychoacoustic results indicate that, at high frequencies (above about 2 kHz), the localization of the stereophonic image within a Critical band is determined by the temporal envelope and not by the temporal fine structure of the audio signal.

The basic idea for Intensity stereo coding is that for some sub-bands, instead of transmitting separate left and right sub-band samples, only the sum-signal should be transmitted, but with Scale Factors for both the left and right channels, thus preserving the stereophonic image.

Flow diagrams of a stereo encoder and decoder, including intensity stereo mode, are shown in figures C.2 and C.3. First, an estimation should be made of the required bit rate for both left and right channel. If the required bit rate exceeds the available bit rate, the required bit rate should be decreased by setting a number of sub-bands to Intensity stereo mode. Depending on the bit rate needed, sub-bands:

- 16 to 31;
- 12 to 31;
- 8 to 31; or
- 4 to 31,

can be set to Intensity stereo mode. For the quantization of such combined sub-bands, the higher of the bit allocations for left and right channel should be used.

The left and right sub-band signals of the sub-bands in joint stereo mode should be added. These new sub-band signals should be scaled in the normal way, but the originally determined Scale Factors of the left and right sub-band signals should be transmitted according to the bit stream syntax. Quantization and coding of common sub-band samples, and coding of common bit allocation should be performed in the same way as in independent coding of the left and right channel of a stereophonic programme.

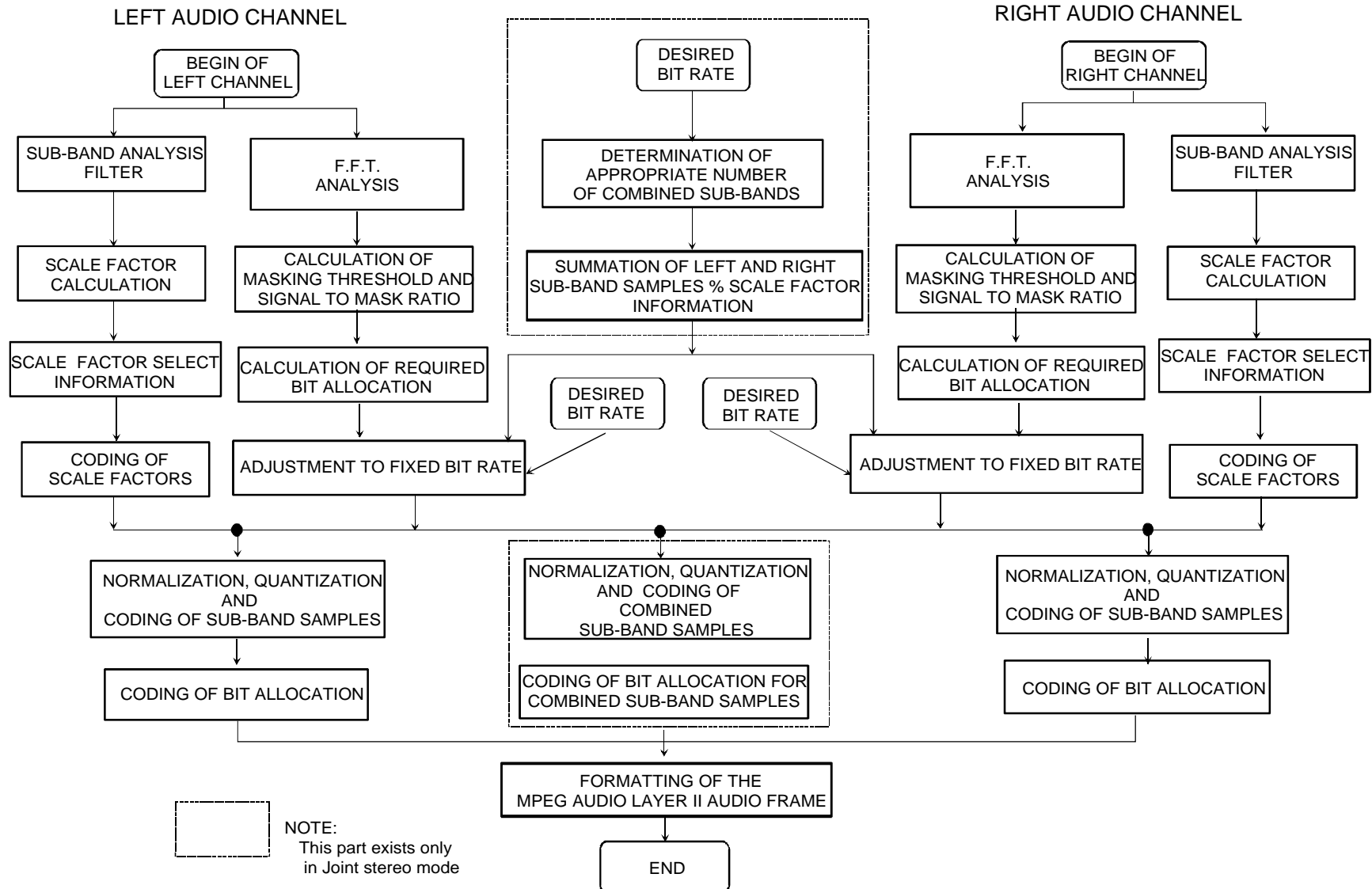
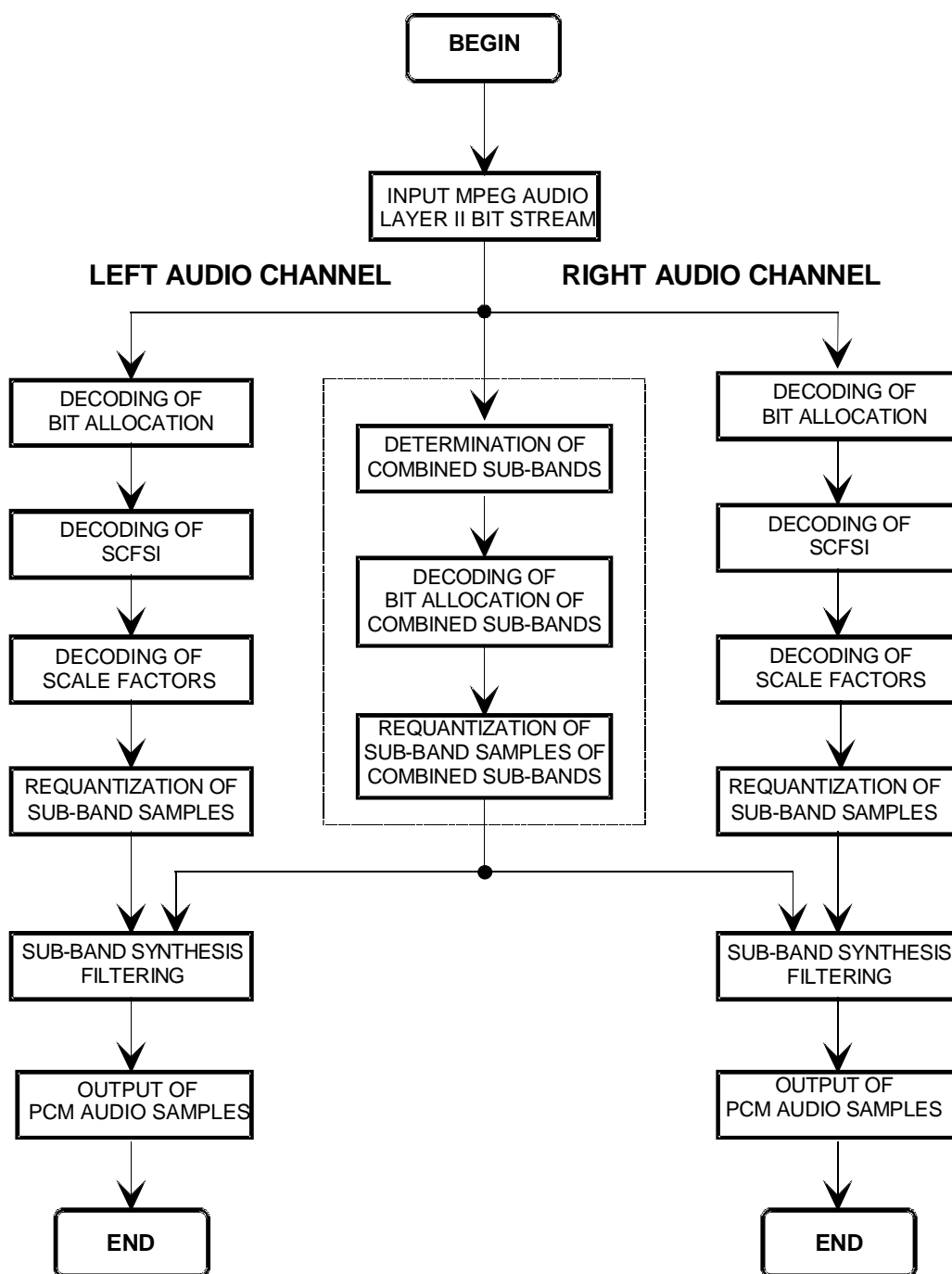


Figure C.2: General MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) Layer II stereo encoder flow chart



NOTE: This part is used only in Joint stereo mode

Figure C.3: General MPEG Audio (ISO/IEC 11172-3 [3] and ISO/IEC 13818-3 [11]) Layer II stereo decoder flow chart

Annex D (informative): Multiplex re-configuration

The data associated with each Logical frame is spread over 16 CIFs as a result of the time interleaving process. This has to be taken into account, when the multiplex is re-configured.

A CU may only be allocated to one sub-channel at a time. Consequently, when the data rate of a sub-channel is changed at the input of the time interleaver, the allocation of CUs to the sub-channel is affected in the following way:

- when the data bit rate is increased, the additional CUs need to be allocated immediately, because some of the bits have zero delay through the time interleaver. During the following 15 CIF periods, only half, on average, of the newly allocated CUs are filled with valid data. The remaining portion contains zero value padding bits;
- when the data bit rate is decreased, the original number of CUs needs to remain allocated to the original sub-channel for another 15 CIF periods, because some of the bits are delayed by 15 CIF periods in the time interleaver. During this period, only half, on average, of the CUs, to be released following the recombination process, are filled with valid data. The remaining portion contains zero value padding bits.

The combination of time interleaving and de-interleaving results in a constant delay of 15 CIF periods. Therefore, every change of bit rate at the input of the time interleaver should be followed by an equivalent change at the output of the de-interleaver 15 CIF periods later.

A multiplex re-configuration is signalled as an event occurring at a given time instant. For sub-channels affected by the re-configuration, the changes of bit rate at the inputs of the time interleavers have to be co-ordinated. The instant of the re-configuration, signalled by the occurrence change, defines the CIF count from which the reallocation of CUs is effective.

As an illustration of the rules, defined in clause 6.5, for co-ordinating the changes in the bit rate and the instant of re-configuration, the following examples are given. In all cases, it is assumed that the multiplex re-configuration occurs between CIFs of time index r_o-1 and r_o . Only a change of error protection profile in the convolutional encoders is considered in these examples:

- a) **change in sub-channel position only:** the convolutional encoder is not affected;
- b) **new sub-channel defined:** if a new sub-channel appears at $r = r_o$ (which did not exist at $r = r_o-1$) then the convolutional encoder uses the corresponding Protection profile for $r \geq r_o$;
- c) **sub-channel removed:** if a sub-channel disappears at $r = r_o$ (which did exist at $r = r_o-1$) then the convolutional encoder ceases encoding at $r = r_o-15$;
- d) **sub-channel capacity increased:** if a sub-channel increases its number of CUs between CIF of time index $r = r_o-1$ and $r = r_o$, then the convolutional encoder uses the new Protection profile for $r \geq r_o$;
- e) **sub-channel capacity decreased:** if a sub-channel decreases its number of CUs between CIF of time index $r = r_o-1$ and $r = r_o$, then the convolutional encoder uses the new Protection profile for $r \geq r_o-15$;
- f) **change in protection profile:** if the Protection profile changes between $r = r_o-1$ and $r = r_o$, but the number of CUs remains unchanged, then the convolutional encoder uses the new Protection profile for $r \geq r_o$.

As a further illustration, figure D.1 shows how two sub-channels exchange capacity during two multiplex reconfigurations (cases d) and e) above) At the first re-configuration, sub-channel 1 increases from 4 CUs to 6 CUs and sub-channel 2 decreases from 6 CUs to 4 CUs. The second re-configuration restores the original situation.

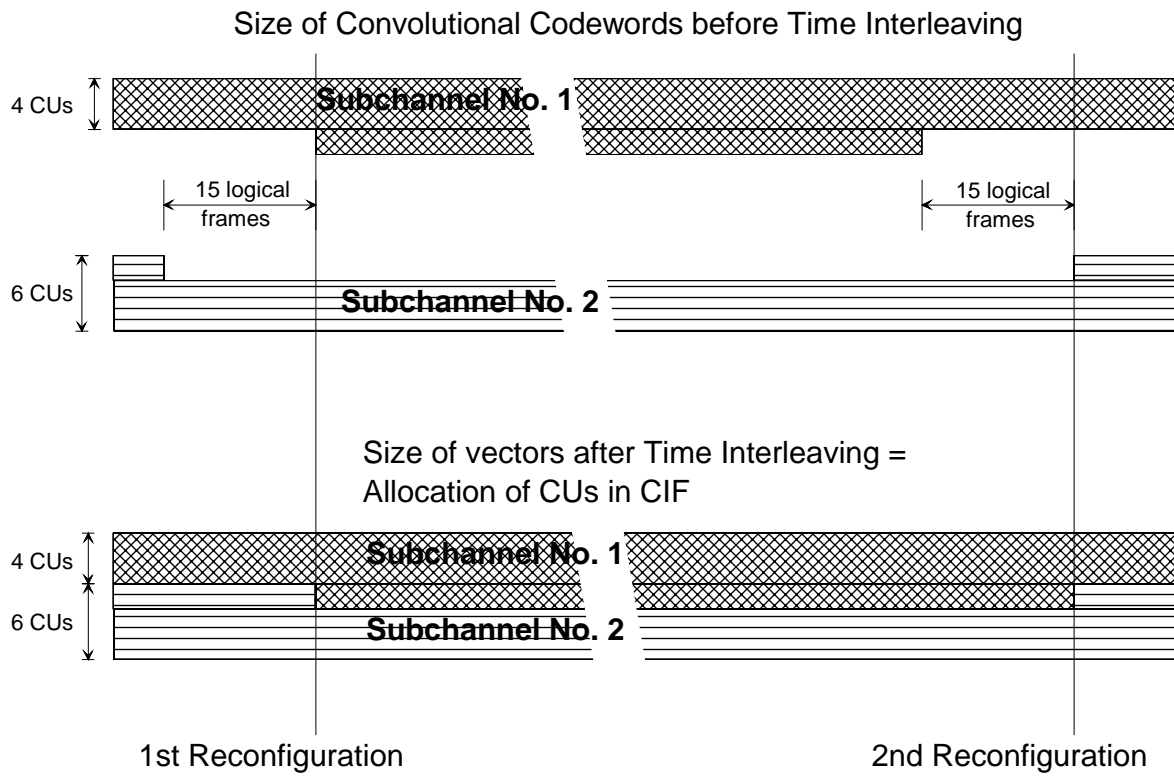


Figure D.1: Example of multiplex re-configuration

Annex E (normative): Calculation of the CRC word

The implementation of Cyclic Redundancy Check codes (CRC-codes) for audio and data transmission allows the detection of transmission errors at the receiver side. For this purpose CRC words shall be included in the transmitted data. These CRC words shall be defined by the result of the procedure described in this annex.

A CRC code is defined by a polynomial of degree n :

$$G(x) = x^n + g_{n-1}x^{n-1} + \dots + g_2x^2 + g_1x + 1$$

with $n \geq 1$

and $g_i \in \{0,1\}$, $i = 1 \dots n-1$

The CRC calculation may be performed by means of a shift register containing n register stages, equivalent to the degree of the polynomial (see figure E.1). The stages are denoted by $b_0 \dots b_{n-1}$, where b_0 corresponds to 1, b_1 to x , b_2 to x^2 , ..., b_{n-1} to x^{n-1} . The shift register is tapped by inserting XORs at the input of those stages, where the corresponding coefficients g_i of the polynomial are "1".

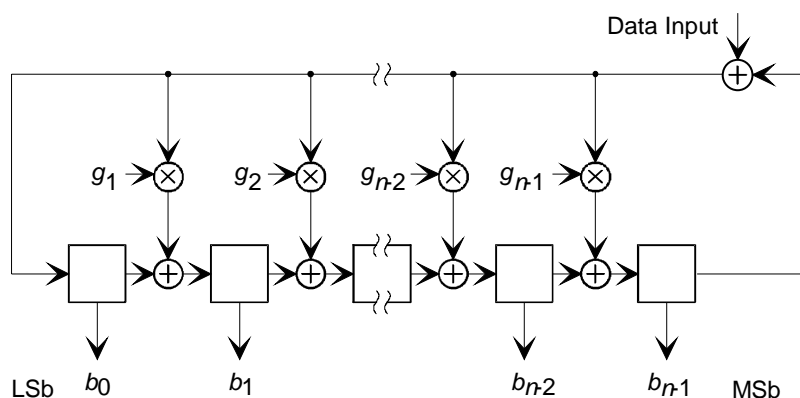


Figure E.1: General CRC block diagram

At the beginning of the CRC calculation, all register stage contents are initialized as specified in the respective clauses, either to all ones or to all zeros. After applying the first bit of the data block (MSb first) to the input, the shift clock causes the register to shift its content by one stage towards the MSb stage (b_{n-1}), while loading the tapped stages with the result of the appropriate XOR operations. The procedure is then repeated for each data bit. Following the shift after applying the last bit (LSb) of the data block to the input, the shift register contains the CRC word which is then read out. Data and CRC word are transmitted with MSb first.

The CRC codes used in the DAB system shall be based on the following polynomials:

$$G(x) = x^{16} + x^{12} + x^5 + 1;$$

$$G(x) = x^{16} + x^{15} + x^2 + 1;$$

$$G(x) = x^8 + x^4 + x^3 + x^2 + 1.$$

The assignment of the polynomials to the respective applications are given in clauses 5.2.1, 5.3.2.3, 5.3.3.3, B.2 and B.3. These clauses also indicate the size and the content of the associated data blocks, the initialization of the shift register and a possible inversion (1's complement) of the CRC word prior to transmission.

Annex F (informative): Bibliography

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History

Document history		
Edition 1	February 1995	Publication as ETS 300 401
Edition 2	May 1997	Publication as ETS 300 401
V1.3.2	September 2000	Publication
V1.3.3	May 2001	Publication
V1.4.1	January 2006	One-step Approval Procedure OAP 20060526: 2006-01-25 to 2006-05-26