TECHNICAL SPECIFICATION

IEC TS 61334-5-4

First edition
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Distribution automation using distribution line carrier systems –

Part 5-4:
Lower layer profiles –
Multi-carrier modulation (MCM) profile

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- The subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

IEC 61334-5-4, which is a technical specification, has been prepared by IEC technical committee 57: Power system control and associated communications.

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

Enquiry draft	Report on voting
57/479/CDV	57/517/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

A bilingual version of this publication may be issued at a later date.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

- transformed into an International Standard;
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

DISTRIBUTION AUTOMATION USING DISTRIBUTION LINE CARRIER SYSTEMS –

Part 5-4: Lower layer profiles – Multi-carrier modulation (MCM) profile

1 Scope and object

This technical specification describes the requirements of the multicarrier modulation (MCM) approach which incorporates the services provided by the physical layer entity and the MAC sublayer with the purpose of building up a set of standards for effective communication on MV and LV network for distribution line carrier (DLC) systems, in the context of IEC 61334-1-1.

Different technical approaches in developing communication systems for DLC communication are in progress. As a consequence, at present, different lower layer profiles are feasible with acceptable results in terms of performance and cost-effectiveness. In many cases, the differences amongst solutions are minor and it is possible to find a common root.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61334. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61334 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 61334-1-1, *Distribution automation using distribution line carrier systems – Part 1: General considerations – Section 1: Distribution automation system architecture*

IEC 61334-3-1, *Distribution automation using distribution line carrier systems – Part 3-1: Mains signalling requirements – Frequency bands and output levels*

IEC 61334-4-1, *Distribution automation using distribution line carrier systems – Part 4: Data communication protocols – Section 1: Reference model of the communication system*

3 Definitions and abbreviations

3.1 Definitions

For the purpose of this part of IEC 61334, the following definitions apply.

3.1.1
control direction
communication direction from the central system to a field device

3.1.2
domain
logical section of a DLC communication network

3.1.3
hops
number of *routing repetitions* required for communication between the master and a specific station

3.1.4
initiator
a station that controls medium access for one *domain*. The *master station* may delegate its 'initiatorship' for a limited time to one of the *slave stations* registered in its domain

NOTE Being an initiator is a dynamic property of a station.

3.1.5
initiator PDU
a PDU that is sent from an *initiator* to a *non-initiator*, possibly using *routing repeaters* for multi-hop communication

3.1.6
master station
station that works as communication master for a *domain*

NOTE Being a master station is a static property of a station.

3.1.7
monitoring direction
communication direction from a field device to the central system

3.1.8
non-initiator
a *station* that is not in the initiator role

NOTE Being a non-initiator is a dynamic property of a station.

3.1.9
non-initiator PDU
a PDU that is sent from a *non-initiator* to an *initiator*, possibly using *routing repeaters* for multi-hop transmission

NOTE Non-initiator PDUs are only sent in reaction to *initiator PDUs*.

3.1.10
routing repetition
re-sending a PDU with a modified address field because the destination station cannot communicate directly with the source station. The routing repetition procedure does not involve a network layer but is located in the MAC sublayer instead. A synonymous for routing repetitions is forwarding in the mobile communications context

3.1.11
slave station
station that works as a communication slave within a *domain*. It normally operates as *non-initiator*, but may be switched to operate as *initiator*

NOTE Being a slave station is a static property of a station.

3.2 Abbreviations

DLC	Distribution line carrier
DMT	Discret multitone
HV	High voltage
LLC	Logical link control

LMI	Layer management interface
LV	Low voltage
M_SDU	MAC layer service data unit
MCM	Multicarrier modulation
MIB	Management information base
MV	Medium voltage
OFDM	Orthogonal frequency division multiplex
P_SDU	Physical layer service data unit
PDU	Protocol data unit
SDU	Service data unit
SMAP	System management application process

4 Lower layer profile structure

The MCM lower layer profile exhibits the structure shown in the following figure. This technical specification describes the function of the physical layer and the MAC sublayer.

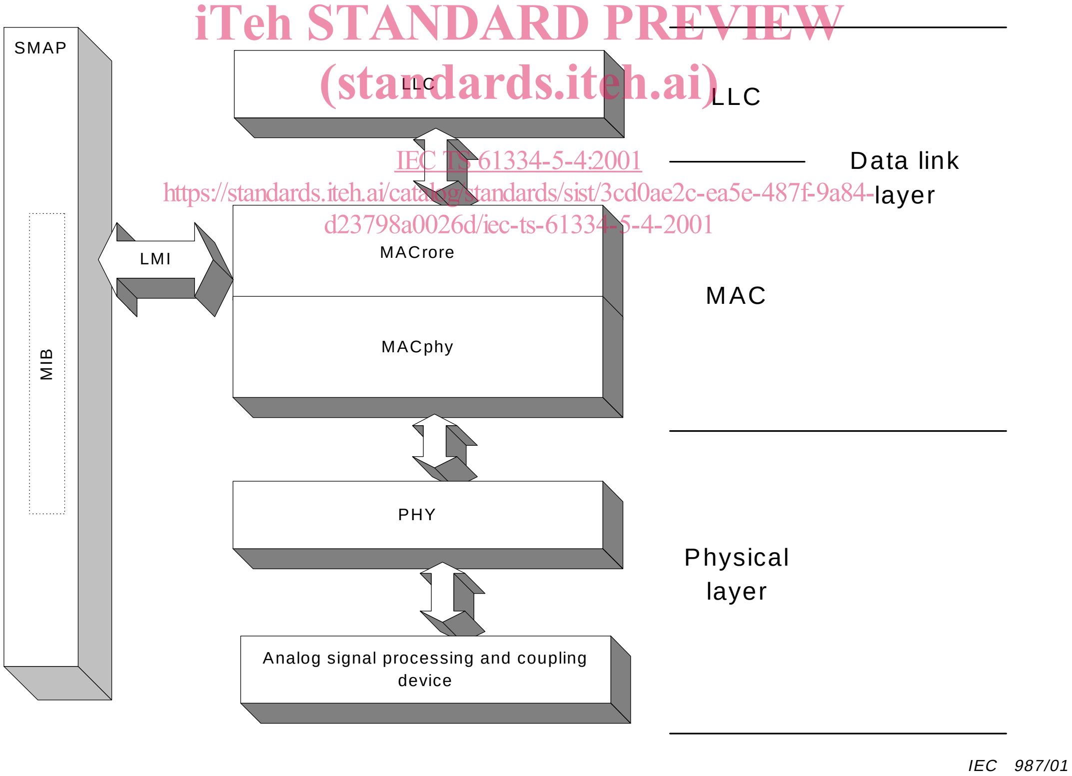

Figure 1 – Layered architecture of the DLC-M protocol stack

4.1 Physical layer

The physical layer provides services to the MAC sublayer to transfer a MAC protocol data unit to a remote MAC sublayer entity. It is independent of the physical characteristics and the implementation of the mains attachment unit.

4.2 MAC sublayer

The MAC sublayer provides services to the LLC sublayer and uses services of the physical layer to transmit LLC PDUs to a remote station. The main functions of the MAC sublayer are error detection and control of medium access.

Furthermore, it provides means for repeater usage which is transparent to the higher protocol layers.

For better understanding, the MAC sublayer is further subdivided into two functional units denoted as MACphy and MACrore. MACphy denotes the part of the MAC sublayer responsible for interfacing to the physical layer, whereas MACrore denotes the part of the MAC sublayer that interfaces the LLC sublayer and is responsible for addressing and routing repetitions.

5 Physical layer specification

5.1 Modulation

5.1.1 Purpose

Multicarrier modulation (MCM), also known as orthogonal frequency division multiplex (OFDM) or discrete multitone (DMT) is a modulation technique which combines an excellent bandwidth efficiency (high data rates) with the possibility of a very flexible bandwidth allocation. In combination with error correction coding, MCM is very robust in presence of narrowband jammers, impulsive noise, and frequency selective attenuation, as typically seen on power lines.

5.1.2 The multicarrier modulation (MCM) principle

In multicarrier modulation, the channel bandwidth is divided into a number of sub-channels. In each sub-channel, a carrier is modulated at a much lower data-rate. A multicarrier modulation scheme can be viewed as consisting of N independently modulated carriers with different carrier frequencies. If the carrier frequencies are selected appropriately, the various carriers are orthogonal, so that they do not interfere with each other. A sample representation of a multicarrier modulated signal in the frequency is shown in figure 2.

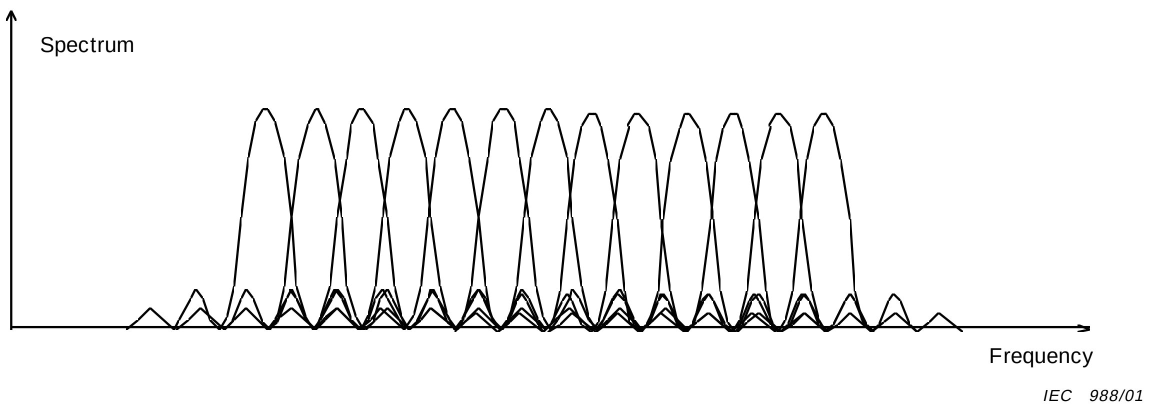

Figure 2 – Sample frequency representation of multicarrier modulation

There are several advantages of the multicarrier modulation scheme as compared to traditional single carrier or spread spectrum systems:

– MCM achieves a much higher bandwidth efficiency than spread spectrum systems. If the bandwidth of each carrier is sufficiently small, a data-rate close to the theoretical Shannon limit can be achieved;

– MCM allows an extremely flexible allocation and use of a given channel bandwidth. As an example, the lower and the upper limit of the used frequency band can be easily configured. In addition, certain frequencies inside this frequency band can be suppressed, for example to prevent interference with other systems. It is also possible to use two or more non-contiguous sub-bands for the transmission of a single data stream;

– each of the carriers can be modulated individually, with different modulation schemes, if appropriate. Typical examples of carrier modulation schemes are FSK, PSK, and QAM, with a different number of bits per carrier. With this flexible choice, the available signal to noise ratio can be used optimally for each carrier;

NOTE 1 The peak power required for a large number of carriers is about 10 dB higher than that of a single-carrier system. However, there are known ways to reduce the peak power of traditional MCM without affecting its performance.

– MCM is considerably more robust against intersymbol interference (ISI) or group delay distortion caused by the transmission channel than narrowband systems. This is mainly due to the fact that the parallel transmission on several carriers leads to a longer symbol duration. Furthermore, ISI can be completely eliminated by inserting guard intervals or a cyclic prefix between the symbols;

– MCM is robust in presence of narrowband interferers (continuous wave noise), because such jammers typically destroy only a single carrier. With proper forward error correction coding, the destroyed bits can be reconstructed;

– in combination with a well-designed interleaver and forward error correction coding scheme, MCM can be made robust against impulsive noise.

NOTE 2 This implies a more complex receiver structure, compared with, for example a simple FSK receiver, but the advantages listed above more than justify the use of MCM. There are FFT-based receiver structures whose complexity increases with $M \log_2 M$, where M is the number of carriers.

Due to the block processing of the MCM demodulator, an inherent transmission delay is introduced. However, for typical power line communication applications this delay is negligible.

5.2 Physical layer data format

5.2.1 Purpose

This clause covers the services required for the PHY layer and the transmission methods which are used to provide the information flow through the physical channel (power distribution network).

5.2.2 Transmission method, overview

This subclause specifies the transmission method of the MCM profile. The chosen modulation scheme is multicarrier differential phase shift keying with I carriers (IC-DPSK). The carrier frequencies are multiples of 4,5 kHz and the number I and the carrier frequencies are configurable. I bits per symbol are transmitted, leading to a gross data rate of I·4,5 kbit/s. To increase the robustness with respect to channel impairments, a rate 1/2 convolutional code is used and the length information and the integrity of a telegram are checked with cyclic redundancy check codes. The synchronization preamble assures a robust synchronization even in bad channel conditions.

To improve the performance in channels with a large group delay distortion, a cyclic prefix of configurable length can be used for the modulation of the payload. The synchronization preamble is always transmitted without cyclic prefix.

The data is transmitted with 288 k samples per second (64 samples per symbol[1]). In the receiver, the signal is sampled at 288 kHz and a 64 point FFT is performed.

[1] When a cyclic prefix is used, there are N_{SS} samples per symbol.

It is assumed that the P_SDU Q(m), m = 0..8M–1, Q(m) ∈ [0,1] is to be transmitted with I bits/symbol using I subcarriers. The length information and the payload are each protected with a separate CRC. The resulting bit stream is padded and segmented into blocks which are interleaved and encoded. The data are then prepended by the synchronization sequence and modulated, see figure 3. A detailed description of each function is given below.

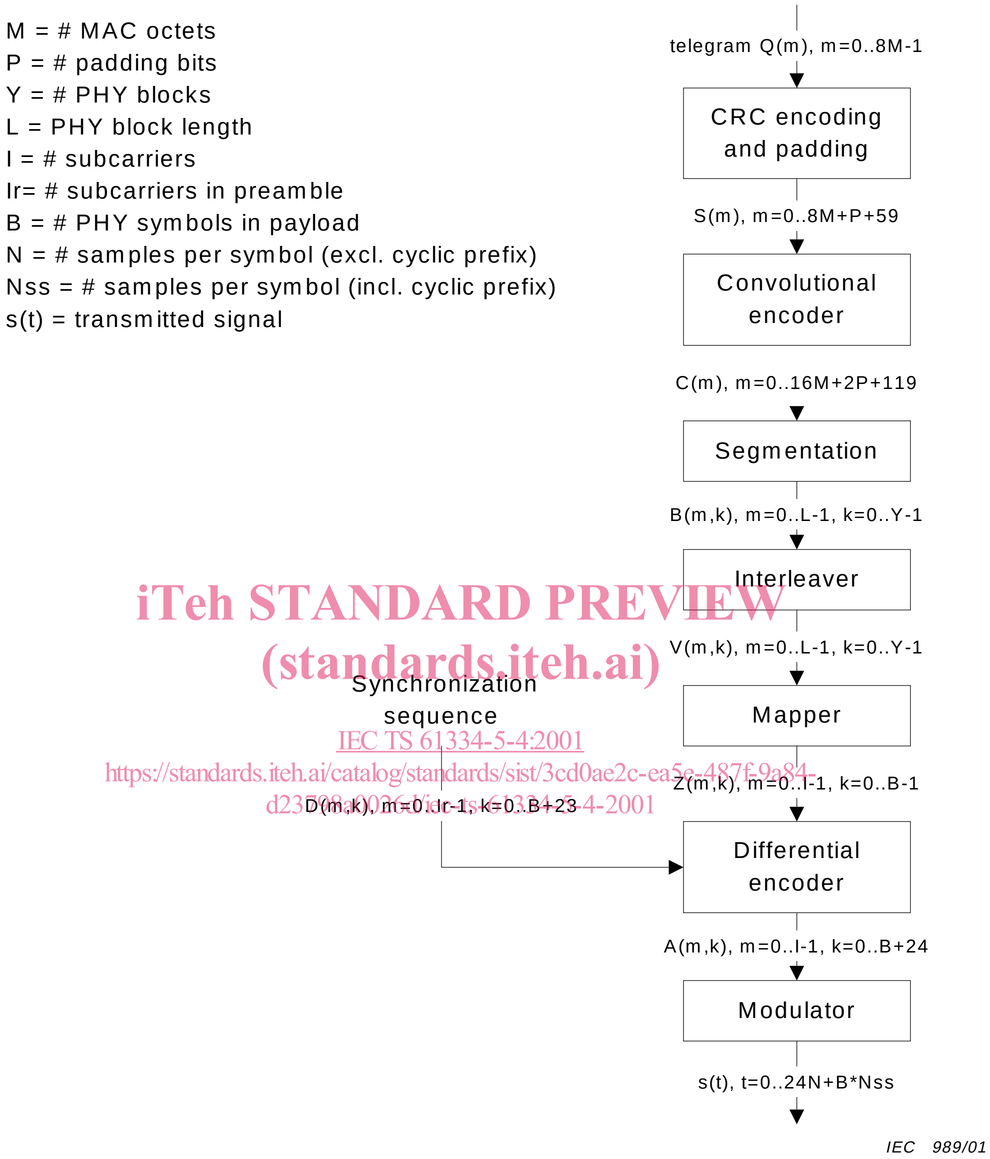

Figure 3 – Transmitter data flow diagram (one telegram)

5.2.3 Configuration parameters

The physical layer as described below is specified by the following design parameters, which can be configured in the network or adapted to the changing channel conditions. These parameters have to be identical in a network to achieve compatibility.

– *Number I of subcarriers* 1 ≤ I ≤ N/2–1. A typical value is N = 64.

– *Indices i_1 to i_I of subcarriers* The subcarrier frequency is i_x·288 kHz /N, 1 ≤ i_x ≤ N/2–1. This permits usage of non-contiguous frequency bands. Theoretical frequency range is from 288 kHz/N to 144–288/N kHz (i.e. excluding i_x = 0 and i_x = N/2). Practical frequency range to be chosen in accordance with IEC 61334-3-1.