TECHNICAL SPECIFICATION

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First edition
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Distribution automation using distribution line carrier systems –

Part 5-5: Lower layer profiles – Spread spectrum-fast frequency hopping (SS-FFH) profile

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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DISTRIBUTION AUTOMATION USING DISTRIBUTION LINE CARRIER SYSTEMS –

Part 5-5: Lower layer profiles – Spread spectrum-fast frequency hopping (SS-FFH) profile

FOREWORD

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- 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 61334-5-5, 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
57/489/CDV	57/518/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.

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- withdrawn;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.

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

INTRODUCTION

This technical specification describes a new physical layer variant with respect to the already defined modulation techniques FSK and S-FSK within the IEC 61334 series (IEC 61334-5-1 and IEC 61334-5-2 [1])).

The SS-FFH profile outlined in this technical specification basically incorporates spread spectrum modulation techniques. It offers the main advantages of very high robustness and improved EMI characteristics without sharing classical spread spectrum drawbacks such as exaggerated bandwidth demand or impractical realization.

The profile specifies the physical layer including the transmission methods and the services provided by both the physical layer and medium access sublayer entities.

[1]) IEC 61334-5-1, *Distribution automation using distribution line carrier systems – Part 5-1: Lower layer profiles – The spread frequency shift keying (S-FSK) profile*

IEC 61334-5-2, *Distribution automation using distribution line carrier systems – Part 5-2: Lower layer profiles – Frequency shift keying (FSK) profile*

DISTRIBUTION AUTOMATION USING DISTRIBUTION LINE CARRIER SYSTEMS –

Part 5-5: Lower layer profiles – Spread spectrum-fast frequency hopping (SS-FFH) profile

1 Scope and object

This technical specification describes the requirements of the spread spectrum-fast frequency hopping (SS-FFH) approach for distribution line carrier communication systems. It incorporates the primitives provided by the physical and MAC layer entities as well as the modulation and transmission methods.

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 61000-3-8, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 8: Signalling on low-voltage electrical installations – Emission levels, frequency bands and electromagnetic disturbance 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*

IEC 61334-4-32, *Distribution automation using distribution line carrier systems – Part 4: Data communication protocols – Section 32: Data link layer – Logical Link Control (UC)*

ITU-T Recommendation V.42, *Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion*

3 Abbreviations and definitions

For the purpose of this technical specification, the following abbreviations and definitions apply.

3.1 Abbreviations

DA	Destination_address
DLC	Distribution Line Carrier
FFH	Fast Frequency Hopping
LV	Low Voltage
M_PDU	MAC Layer Protocol Data Unit
M_SDU	MAC Layer Service Data Unit
MAC, M, MA	Medium Access Control
MV	Medium Voltage
P_PDU	Physical Layer Protocol Data Unit
P_SDU	Physical Layer Service Data Unit
SC	Service_class
SDU	Service Data Unit
SS	Spread Spectrum

3.2 Definitions

3.2.1
chip
sinusoidal carrier waveform of limited time duration. Sequences of four chips form one symbol

3.2.2
domain
logical section of a DLC network

3.2.3
hops
number of routing repetitions required for communication between the master and a specific station

3.2.4
preamble
modulated signal sequence that precedes a data frame for synchronization purpose

3.2.5
routing repetition
re-sending a PDU with a modified protocol information field because the destination station can not be reached directly by the source station. The routing repetition procedure concerns only the protocol information field and is handled by the MAC sublayer

3.2.6
symbol
modulated signal that encodes two transmitted bits

4 Physical layer

4.1 Purpose

This clause details the transmission method to transport data frames provided by the MAC sublayer to and from peer MAC entities using the electrical low-voltage distribution network. It also specifies the requirements for the logical interface between the physical layer and the MAC sublayer.

4.2 Electrical characteristics

The physical layer interfaces directly with the low-voltage distribution wiring as transport medium. The electrical characteristics of the distribution network are AC, 230 V, 50/60 Hz. Network coupling may be either single- or three-phase.

4.3 Modulation principle

The modulation method is spread spectrum fast frequency hopping (SS-FFH) modulation. The basis of SS-FFH are time-limited sinusoidal carrier waveforms of a certain time duration T_C and different frequencies f_i $i = 1 \dots M$. These carrier bursts are called chips. The reciprocal of the chip time duration T_C is called chip rate R_C. An information symbol is encoded by a sequence of subsequential chips as seen in figure 1.

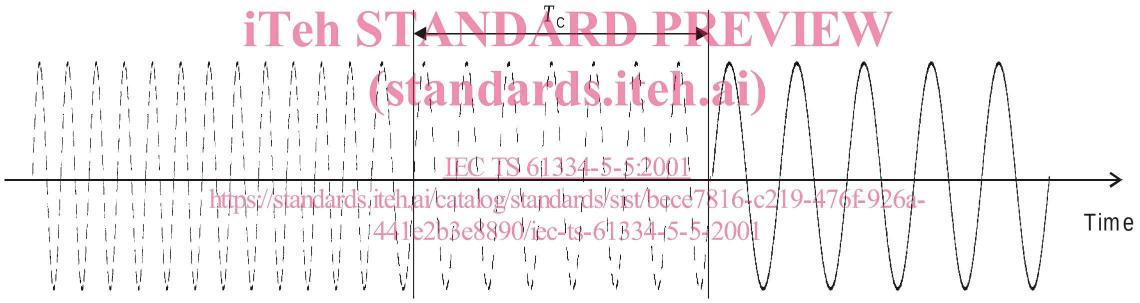

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Figure 1 – Time representation of M = 3 SS-FFH symbol

Each frequency is used only once per sequence. For this reason, the number of symbols that can be encoded this way is M.

An example for M = 4 is given in the following.

Symbol	Bitmapping
S_1	00
S_2	01
S_3	10
S_4	11

Chip 1	Chip 2	Chip 3	Chip 4
f_1	f_2	f_3	f_4
f_2	f_3	f_4	f_1
f_3	f_4	f_1	f_2
f_4	f_1	f_2	f_3

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Figure 2 – Coding of information symbols in sequence of carrier chips

The mapping of symbols into two bit patterns is also shown in figure 2. The maximum number of bits that can be encoded with M different symbols is ld M. Thus the data rate R_D given the chip rate R_C is

$$R_D = \frac{R_C}{M} \times \text{ld}\,(M)$$

Spreading the information in the described way on numerous carriers has several advantages. First-symbol detection is possible with only one carrier present which makes SS-FFH very robust against interference. Second EMI regulations can be met more easily through the fact that the signalling energy is not confined to a narrow spectral segment.

SS-FFH provides the robustness unique to spread spectrum systems without sharing the drawbacks such as complicated synchronization or expensive system implementation.

4.4 Receiver principle

Demodulation and detection of symbols follows a soft decision algorithm. This means that quasi-analogue values for the presence or non-presence of each chip of a symbol are used for detection.

Four demodulated signals, one for each frequency j = 1 ... 4, are used for symbol detection for each of the subsequent chips k = 1 ... 4. As an example of a receiver architecture the receiver sums up the demodulated signals d_{jk} for four possible symbols.

$$DS_1 = d_{11} + d_{22} + d_{33} + d_{44}$$

$$DS_2 = d_{21} + d_{32} + d_{43} + d_{14}$$

$$DS_3 = d_{31} + d_{42} + d_{13} + d_{24}$$

$$DS_4 = d_{41} + d_{12} + d_{23} + d_{34}$$

Finally the symbol i with the largest sum DS_i is chosen.

NOTE Actual receiver realization has no influence on interoperability.

4.5 Synchronization

4.5.1 Bit timing

The basic timing unit is

$$t_B = 1/(6f_N)$$

where f_N denotes the mains frequency, for example, 50 Hz or 60 Hz.

Shorter intervals for bit timing may be generated by subdividing the basic unit. The basic unit itself is generated by dividing the time period between two voltage zero crossings of one phase by three. The beginning of a basic timing unit is demarked by basic timing markers. This procedure ensures synchronization of the basic timing units of any transmitter and receiver within a three-phase low-voltage network.

NOTE 1 Transmission delays are negligible for the data rates and typical distances considered in this document.

NOTE 2 Without violating the synchronization condition, fixed phase shifts between zero crossings and basic timing markers may be introduced. This phase shift must not be time variant and must be constant for the overall system.

4.5.2 Chip timing

The beginning of a chip sequence is demarked by the aforementioned bit timing.

Given a chip rate R_C, the symbol rate R_S is an integer multiple of R_C:

$$R_S = K \times R_C$$

4.5.3 Frame synchronization

Synchronization of frames is accomplished by preambles preceding the data frame. A pre-defined sequence of eight symbols is used for this purpose. Acknowledging that accurate preamble detection is mandatory for good overall system performance, two principles are deployed:

- preamble chip rate is substantially lower than data chip rate;
- a soft decision preamble detection algorithm is used. [1)]

The following binary sequence is used as a preamble.

Bit	1	0	0	1	0	1	1	1	0	0	1	0	0	0	1	1
Symbol	S_3		S_2		S_2		S_4		S_1		S_3		S_1		S_4	

The suggested preamble chip rate is half the data chip rate, resulting in a signalling energy which is two times higher for each transmitted symbol.

4.5.4 Enhanced bit synchronization

Synchronization may be enhanced by additionally using the preamble sequence for fine tuning of the chip timing.

4.6 Frequency sets

Any frequency in the range 9 kHz to 95 kHz, which is a multiple of 2,4 kHz may be chosen for signalling. Due to heavy interference at lower frequencies the upper end of this band is preferable. Suggested frequencies are 52,8 kHz, 62,4 kHz, 72 kHz and 86,4 kHz.

4.7 Physical frame encapsulation (see table 1 and figure 3)

Each physical layer data frame (P_PDU) consists of the physical layer data unit (P_SDU) and a preceding preamble (see 4.5.3).

Table 1 – P_PDU fields and rates

	Preamble	P_SDU
Length	8 symbols	26 octets
Chip rate	0,5 R_C	R_C

[1)] The actual preamble detection algorithm does not affect compatibility.