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Kabelska omrežja za televizijske in zvokovne signale ter interaktivne storitve – Sistemske smernice za analogne optične prenosne sisteme

(istoveten CLC/TR 50460:2005)

Cable networks for television signals, sound signals and interactive services – System guidelines for analogue optical transmission systems

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English version

Cable networks for television signals, sound signals and interactive services – System guidelines for analogue optical transmission systems

Réseaux de distribution par câbles pour signaux de télévision, signaux de radiodiffusion sonore et services interactifs – Lignes directrices pour les systèmes de transmission optique analogiques

Kabelnetze für Fernsehsignale, Tonsignale und interaktive Dienste – System-Leitfaden für analoge optische Übertragungssysteme

This Technical Report was approved by CENELEC on 2005-05-21.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

Standards are very important sources of information on terms, definitions and minimum requirements for technical products. EN 60728-6 is such a standard for optical equipment used in cable networks for television signals, sound signals and interactive services. However, a lot of additional information and knowledge is needed for designing and planning complete optical transmission systems. This kind of information is not suitable for a standard because system engineers need freedom in their methods of finding economical solutions for special needs. CENELEC TC 209 therefore decided to develop this Technical Report which provides guidelines in how to use EN 60728-6 for planning analogue optical transmission systems.

This Technical Report was prepared by the Technical Committee CENELEC TC 209, Cable networks for television signals, sound signals and interactive services.

The text of the draft was submitted to the formal vote and was approved by CENELEC as CLC/TR 50460 on 2005-05-21.

Contents

1 Scope

1.1 General

Standards of the EN 50083 and EN 60728 series deal with cable networks for television signals, sound signals and interactive services including equipment, systems and installations

- for headend-reception, processing and distribution of sound and television signals and their associated data signals and
- for processing, interfacing and transmitting all kinds of signals for interactive services using all applicable transmission media.

All kinds of networks like

- CATV-networks
- MATV- and SMATV-networks
- individual receiving networks

and all kinds of equipment, systems and installations installed in such networks, are within this scope.

The extent of this standardisation work is from the antennas, special signal source inputs to the headend or other interface points to the network up to the terminal input.

The standardisation of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals etc.) as well as of any coaxial and optical cables and accessories thereof is excluded.

1.2 Scope of this Technical Report

This Technical Report provides guidelines and procedures for determining the overall performance of optical transmissions systems used in cable networks for television signals, sound signals and interactive services. It is based on the requirements for optical equipment defined in the standard EN 60728-6 (Cable networks for television signals, sound signals and interactive services – Part 6: Optical equipment) and should be used together with this standard. The information provided is meant to help field engineers and network planners (system designers) in planning and designing optical systems. Though this content is less dense than in a standard, basic knowledge about system parameters of cable networks is needed.

2 Normative references

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

EN 50083-3	2002	Cable networks for television signals, sound signals and interactive services - Part 3: Active wideband equipment for coaxial cable networks
EN 50083-7 + A1	1996 2000	Cable networks for television signals, sound signals and interactive services - Part 7, System performance
EN 60728-6	2003	Cable networks for television signals, sound signals and interactive services - Part 6, Optical equipment (IEC 60728-6:2003)
EN 60793-2	2004	Optical fibres - Part 2: Product specifications - General (IEC 60793-2:2003)
IEC/TR 61931	1998	Fibre optics – Terminology

3 Terms, definitions, symbols and abbreviations

For the purposes of this technical report, the terms, definitions, symbols and abbreviations given in EN 50083-7, EN 60728-6 and IEC/TR 61931 apply.

3.1 Symbols

Additionally to the symbols given in the above mentioned references, the following graphical symbol is used in the figures of this technical report:

WDM	wavelength division multiplexer

3.2 Abbreviations

Additionally to the abbreviations given in the above mentioned references, the following abbreviations are used in this technical report:

2HD	second harmonic distortion
3HD	third harmonic distortion
DFB	distributed feedback
DWDM	Dense wavelength division multiplex
IIN	induced intensity noise
IMD2	second order intermodulation
IMD3	third order intermodulation
IM-DD	intensity modulation – direct detection
I_r	equivalent input noise current density of an optical receiver
OMI	optical modulation index
MPI	multi-path interference
PMD	polarisation mode dispersion
PMP	point to mulit-point
PTP	point to point
RMS	root mean square
SBS	stimulated Brillouin scattering
WDM	wavelength division multiplexer

4 Topologies used for optical transmission systems in cable networks

The overall performance of optical transmission systems depends on many parameters and conditions. Separating the applications into different categories simplifies the step by step analysis and leads to a better overview. A logical way to build up these categories is to distinguish different network topologies because it can be assumed that the network architecture is always known in advance. Starting from this point of view the following five topologies can be identified as relevant for the user.

4.1 Point to point system

Point-to-point (PTP) systems consist of a single optical transmitter and a single optical receiver connected by a single line of fibre (Figure 6).

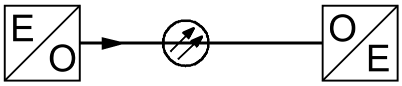

Figure 6 - Point to point (PTP) system

This configuration can typically be found in trunk lines feeding areas cabled with coax (HFC networks). Both wavelengths, 1 310 nm and 1 550 nm, are used for these systems. Most of the optical budget is consumed by the fibres attenuation (long distance system). At 1 550 nm, optical amplifiers can be used to extend the range of this kind of system.

4.2 Point to multi-point system

In point to multi-point (PMP) systems a single optical transmitter feeds more than one optical receiver. The receivers are connected to a main fibre via optical couplers and tap fibres as shown in Figure 7.

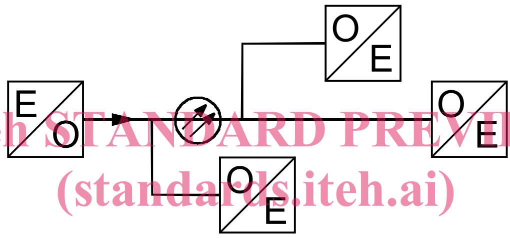

Figure 7 - Point to multi-point (PMP) system

An alternative configuration for feeding more than one receiver from a single transmitter is to use an optical splitter at the transmitter node and individual fibres from the transmitter node to each receiver. This leads to a star topology which should be treated as multiple PTP systems with a single transmitter.

PMP systems are typically used when different coaxial parts of a network shall be supplied with the same signal saving as much fibre as possible (optical distribution systems). Depending on the fibre lengths, both wavelengths are used. At 1 550 nm, optical amplifiers can be used to compensate for the fibre and splitting losses.

4.3 Multi-point to point system

Multi-point-to-point systems consist of at least two transmitters with different wavelengths sending their signals to a common receiver. The transmitter signals may be combined by an optical coupler or if the link loss is critical, by a wavelength multiplexer (Figure 8).

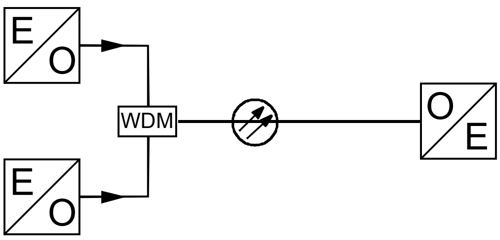

Figure 8 - Multipoint-to-point (WDM) system

Since optical receivers usually have a very broad input wavelength range, the central wavelengths of the transmitters may be extremely different (e.g. 1 310 nm and 1 550 nm). In order to avoid signal mixing in the receiver the optical spectrums of the transmitters have to differ at least by the upper limit of the receivers electrical frequency range. If only signals in the 1 550 nm wavelength range are used, optical amplifiers can be employed for extending the fibre length. Since all input signals of the system are provided at the same system output, different frequency ranges have to be used for modulating the transmitters.

This kind of topology is typically chosen if part of a network shall be provided with signals from different locations.

4.4 Real wavelength division multiplex system

Real wavelength division multiplex systems consist of at least two PTP systems operating on the same fibre. The transmitter signals are combined at the transmitter node with a wavelength multiplexer or if the link loss is not critical, by an optical coupler. At the receiver node the different signals are separated by another wavelength multiplexer and led to individual receivers (Figure 9).

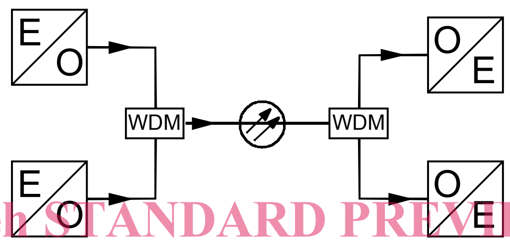

Figure 9 - Real WDM system

For only two different wavelengths this configuration can be built up easily combining a 1 310 nm system and a 1 550 nm system. If wavelength dependent fibre losses can't be tolerated or more than two PTP systems have to be combined, a closer spacing of the wavelengths has to be chosen (DWDM = dense WDM). This is usually done in the 1 550 nm wavelength range. Optical amplifiers can be used to achieve longer link lengths in this case. Care has to be taken to avoid overlapping of the transmitters spectrums. A narrow wavelength spacing means high efforts to control the transmitter wavelengths and high costs for the wavelength division multiplexers.

The main reason for using this configuration is to save fibres. This approach allows to transmit digitally and analogue modulated signals over the same fibre.

4.5 Combinations

The basic configurations described above can be combined to more complex architectures. The best way dealing with such complex structures is to split them up to their basic parts which could be treated separately.

5 Influences of equipment and fibre parameters on the system performance

The performance of analogue optical transmission systems depends not only on various equipment parameters but also on the properties of the fibre installation. Some of these parameters and properties interact in a way making it necessary to look at the transmission system at a whole. The interdependencies between the equipment and system properties and the performance parameters are shown in Table 2. The numbers in the table refer to the clauses of this report containing the relevant information:

Table 2 - Interdependencies between equipment and system properties and the performance parameters

Equipment properties and effects		System performance parameters				
		C/N	*CSO*	*CTB*	Flatness	Output level
TX	OMI	6, 7	6, 8.2	6, 8.1	(9)	6, 10
	CSO		8.1			
	CTB			8.2		
	linewidth	B.1.2				
	chirping	7.2	C.3.7.1, C.3.7.2	C.4.1		
	RIN	7				
	power	7				10
	λ	(7.3)				
	flatness				9	
RX	I_r	7				
	CSO		8.1			
	CTB			8.2		
	flatness				9	
	AGC range				9	10
OFA	*F*	7.4				
	power	7.4				10
	gain	7.4	(8.1.2)	(8.2)		
	λ	7.4				
Fibre	dispersion		C.3.7.1, C.3.7.2	(8.2)		
	SBS	(7.2)	(8.1.2)	(C.4.3)		
	SPM		C.3.10			
	PMD		(8.1.1)			
	loss	7				10
Passive	return loss	(B.1.3)				
	PDL		(C.3.7.2)			
	loss	7				10
X: relevant		(X): can be relevant				

This table can be used as an entry point and quick reference to the contents of this report.

6 Optical modulation index

The optical modulation index (OMI) is one of the most important parameters of analogue optical links. It has to be chosen very carefully in order to obtain the best carrier to noise ratio without getting too much distortion due to clipping effects (see C.3.3).

Working with OMIs two cases have to be considered: single wavelength systems and wavelength division multiplex (WDM) systems.

6.1 Single wavelength system

The definition of the OMI is very similar to the definition of the modulation index in ordinary AM-modulation. An illustrative explanation of this definition is shown in Figure 10.

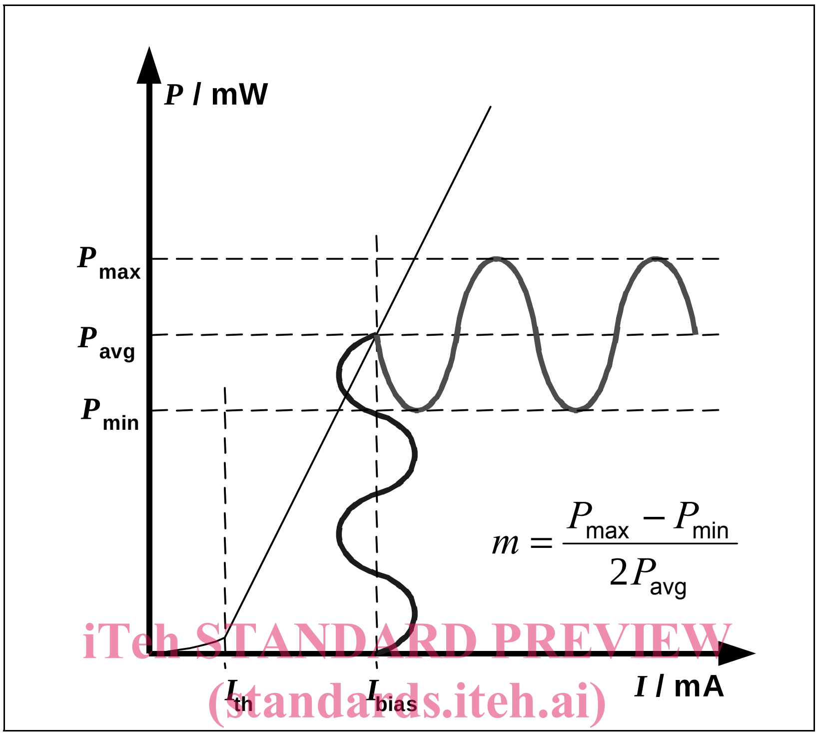

Figure 10 - Definition of OMI for an optical transmitter

The OMI is defined as

$$m = \frac{P_{max} - P_{min}}{P_{max} + P_{min}} = \frac{P_{max} - P_{min}}{2 \cdot P_{avg}} \quad (1)$$

where

m	is the optical modulation index
P_{max}	is the peak optical output power
P_{min}	is the minimum optical output power
P_{avg}	is the mean optical output power

Laser currents below I_{th} lead to clipping, the waveform of the optical output power becomes distorted. The OMI is more than 1 then.

This definition relates to a single channel and a sinusoidal signal. The same definition can also be used with QAM signals if the equivalent power is used to calculate a new peak value of the modulating current. However, the signals transmitted in cable networks are a mixture of a whole bunch of channels containing carriers with various modulation schemes. For each channel an individual OMI can be determined.

Since the peak-to-average ratio of combined signals decreases with the number of channels, the individual OMIs don't add up linearly for the total OMI. The total OMI for several channels is instead calculated by summing the powers of individual carriers:

$$m_{\mathrm{T}} = \sqrt{m_1^2 + m_2^2 + \ldots + m_N^2} \qquad (2)$$

Provided that all channels have equal OMI the formula simplifies to

$$m_{\mathrm{T}} = m\sqrt{N} \qquad (3)$$

The total OMI is a practical value for making estimations of the maximum channel counts or for C/N calculations with a certain number of channels [6]. But the peak-to-average ratio for relatively small numbers of channels can be surprisingly high and clipping may occur at smaller total OMI values than in case of more than 10 channels. For analogue carriers m_{T} = 0,3 is a typical value for 1 310 nm directly modulated transmitter and m_{T} = 0,25 to 0,28 for externally modulated 1 550 nm transmitter.

6.2 WDM systems

In WDM systems outputs of optical transmitters are combined using wavelength division multiplexers or optical couplers. Thereby the average optical output powers add up resulting in a reduced OMI for the individual channels. For the combination of signals from two transmitters the resulting OMI of a channel can be calculated by:

$$m = \frac{m_1 \cdot P_1}{P_1 + P_2} \qquad (4)$$

where

- m_1 is the optical modulation index (OMI) of the channel to be considered, transmitted by the first transmitter
- P_1 is the optical power of the first transmitter at the output of the combining device (optical coupler or WDM)
- P_2 is the optical power of the second transmitter at the output of the combining device (optical coupler or WDM)

For more than two transmitters the denominator has to be replaced by the sum of all powers at the output of the combining device. If the combined signal is fed to an optical receiver, the carrier to noise ratio at its output is lower than with a single optical signal due to the reduced OMIs. Therefore multi-point to point systems are not very popular and true WDM systems with separate receivers for each wavelength are preferred in cable networks. Nevertheless this configuration can be useful for adding narrowcast signals to broadcast signals in existing networks. As equation (4) shows, great care has to be taken by adjusting the power levels of the input signals.

6.3 Choosing the right input level at the transmitter

The OMI is directly related to the driving current of the laser hence to the input level of the transmitter. Therefore choosing the right transmitter input level is crucial for any optical transmission link. Some manufacturers solved this problem by developing special driving amplifier with an automatic gain control (AGC) for their transmitters. This results in a broader input level range for achieving the optimum OMI. Nevertheless even with this kind of solution, the input level should be chosen carefully in order to save the AGC range for unwanted changes in the level or the channel load.

EN 60728-6 requires manufacturers to publish the required input level at which the required performance can be met (see 6.1.1 of EN 60728-6). Starting from this level the optimum input level for a given channel load can be calculated, using the following procedure.