

Fibre optic communication subsystem test procedures —

Part 2-10: Digital systems — Time-resolved chirp and alpha-factor measurement of laser transmitters

The European Standard EN 61280-2-10:2005 has the status of a
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National foreword

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**Fibre optic communication subsystem test procedures
Part 2-10: Digital systems –
Time-resolved chirp and alpha-factor measurement
of laser transmitters
(IEC 61280-2-10:2005)**

Procédures d'essai des sous-systèmes
de télécommunications à fibres optiques
Partie 2-10: Systèmes numériques –
Mesure de la fluctuation de la longueur
d'onde résolue dans le temps et
du facteur alpha des émetteurs laser
(CEI 61280-2-10:2005)

Prüfverfahren für Lichtwellenleiter-
Kommunikationsuntersysteme
Teil 2-10: Digitale Systeme –
Messung von zeitaufgelöstem Chirp
und Alphafaktor von Lasersendern
(IEC 61280-2-10:2005)

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

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Foreword

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The following dates were fixed:

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 2-10: Digital systems – Time-resolved chirp and alpha-factor measurement of laser transmitters

1 Scope

This part of IEC 61280 sets forth standard procedures for measuring time-resolved chirp (TRC) on laser transmitters. The calculation of alpha-factor, a measure of transient chirp, is derived from the measured TRC data. Also covered is a means to verify the TRC set-ups and calculations (Annex A) and a review of laser modulation methods and the relationship of TRC to performance in a transmission system.

2 Background

Understanding the effects of chirp on the transmission of signals is of great importance to the system designer. Chirp can have two separate outcomes in transmission systems. The first is that the chirp can interact with the fibre dispersion to broaden or narrow the pulse along the fibre. This will cause a positive or negative path penalty, which ultimately decreases or increases the distance over which the signal can propagate in a system without regeneration. The sign of the penalty depends upon both the sign of the chirp and the sign of the fibre dispersion. The second is that chirp can broaden the transmitted spectrum limiting the channel spacing by interfering with adjacent channels in an ultra-dense WDM environment, even at short-haul distances.

The path penalty is the apparent reduction of receiver sensitivity due to distortion of the signal waveform during its transmission over the path. A negative path penalty corresponds to an apparent increase of receiver sensitivity. The path penalty is manifested as a shift of the system's bit error ratio (BER) curves toward higher or lower input power levels. A positive chirp penalty is defined as the additional signal-to-noise ratio (SNR) required at the receiver due to laser chirp to maintain a BER in a system with specified dispersion.

Measuring chirp penalty directly is difficult because it requires a chirp-free transmitter with the identical intensity pattern as the device under test (DUT). Because of this difficulty, chirp penalty is often inferred from a path penalty measurement. A path penalty measurement involves substituting a fibre of known chromatic dispersion into the signal path and measuring the additional power (SNR) required to achieve the specified BER. This measurement is tedious and time consuming and assumes that the measurement is dominated by the chirp penalty term. This has led many transmitter and system designers and manufacturers to estimate the chirp (or dispersion) penalty using time-resolved chirp data directly or with derived chirp parameters that are either modelled or measured.

In order to bring the cost of DWDM transmission systems down, lower cost transmitters are being designed and deployed. Controlling the amount of chirp present in these lower cost transmitters is key to their success in the network. [1]¹

3 Abbreviations

BER	Bit-error ratio
DCA	Digital communications analyser
DFB	Distributed feedback laser
DM	Directly modulated laser
DUT	Device under test
DWDM	Dense wavelength-division multiplexing
EAM	Electro-absorption modulator
EDFA	Erbium-doped fibre amplifier
EML	Electro-absorption modulated laser
FFT	Fast Fourier transform
FROG	Frequency-resolved optical gating
FSR	Free spectral range
NRZ	Non-return-to-zero
OSA	Optical spectrum analyser
PMF	Polarisation maintaining fibre
PRBS	Pseudo-random binary sequence
SLM	Single longitudinal mode
SNR	Signal-to-noise ratio
SOP	State of polarisation
TRC	Time-resolved chirp
WDM	Wavelength-division multiplexing

4 Definition of time-resolved chirp

Time-resolved chirp (also referred to as dynamic chirp) is the time variation of the instantaneous optical frequency of a transmitter. Chirp is also expressed in the literature by temporal rate of change of the phase of the propagating electromagnetic wave; as such it is a time derivative and bares units of inverse of time (Hz). [2] It is typically expressed as $\Delta f(t)$, the difference from the average optical frequency. The instantaneous optical power, $P(t)$, is used in conjunction with $\Delta f(t)$ to completely describe the optical signal.

¹) Figures in square brackets refer to the bibliography.

Measurements are acquired in the time domain using a trigger that is synchronous with a pseudo-random binary sequence (PRBS) modulation pattern. As described above, there are two components of TRC measurement. The optical waveform, $P(t)$, is that which would be displayed with a wide-band optical receiver and oscilloscope. The chirp or frequency waveform, $\Delta f(t)$, indicates that the frequency of the laser is also varying as the laser is modulated with the data. Figure 1 shows a typical TRC result.

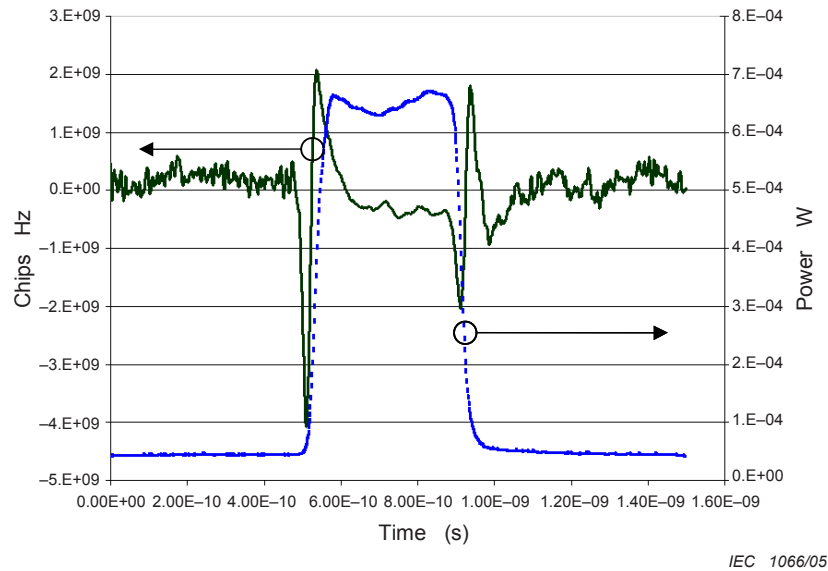


Figure 1 – A typical TRC measurement

5 Modelling transmitter behaviour

In a modulated signal, the frequency variation can be modelled as the sum of phase shift term and frequency shift term. An abrupt shift in phase becomes a transient in frequency. The two terms are generally referred to as *transient* and *adiabatic* respectively. A general equation for chirp is given by [2]:

$$\Delta f(t) = \frac{\alpha}{4\pi} \left[\frac{\frac{dP}{dt}}{P} + K_1 P - \frac{K_2}{P} \right] \quad (1)$$

where $\Delta f(t)$ is the difference from the average optical frequency, α is the alpha-factor, P is the instantaneous optical power, and K_1 and K_2 are adiabatic terms.

Considering only transient chirp, and solving for alpha-factor:

$$\alpha = 4\pi P \frac{\Delta f(t)}{\frac{dP}{dt}} = 2P \frac{\frac{d\phi}{dt}}{\frac{dP}{dt}} = 2 \frac{\Delta\phi}{\frac{\Delta P}{P}} \quad (2)$$

where $\Delta f(t) = \frac{1}{2\pi} \frac{d\phi}{dt}$