

Fibre optic communication subsystem test procedures —

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

ICS 33.180.01

National foreword

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Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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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**

PUBLICLY AVAILABLE SPECIFICATION



INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

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

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The text of this PAS is based on the following document:

This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

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86C/475A/PAS	86C/496/RVD

Following publication of this PAS, the technical committee or subcommittee concerned will investigate the possibility of transforming the PAS into an International Standard.

This PAS shall remain valid for an initial maximum period of 3 years starting from 2002-08. The validity may be extended for a single 3-year period, following which it shall be revised to become another type of normative document, or shall be withdrawn.

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 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 setups 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 BER-curves towards 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 specified bit error ratio (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 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 modeling parameters.

IEC technical report 61282-8 (to be published) describes the estimation of dispersion penalty from measured time-resolved chirp data [8].

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 [7].

3 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. 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.

Measurements are acquired in the time domain using a trigger that is synchronous with a 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.

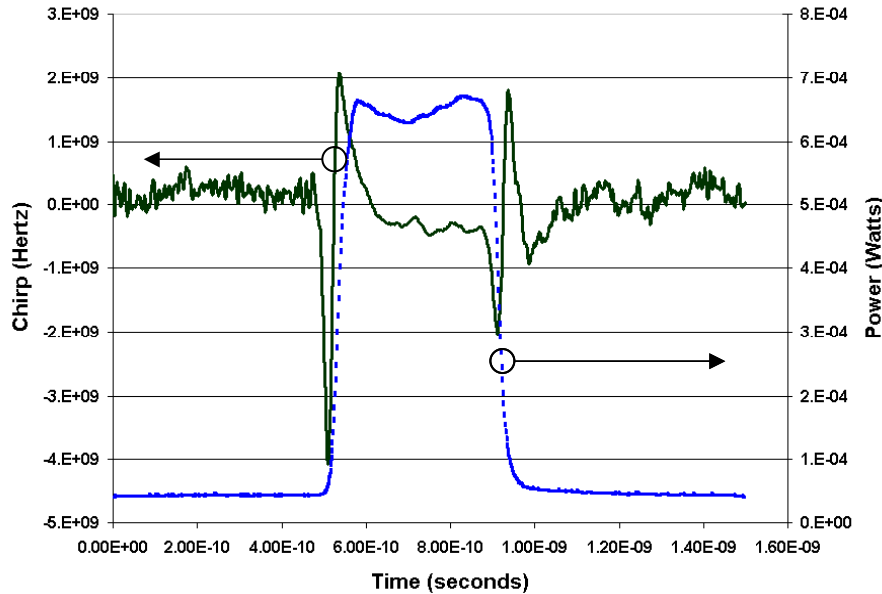


Figure 1– A typical TRC measurement

4 Modeling transmitter behaviour

In a modulated signal, the frequency variation can be modeled 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 [1]:

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

where α is the alpha-factor and K_1 and K_2 are adiabatic terms.

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

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

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

Equation (2) indicates that transient chirp produces a phase shift ($\Delta\phi$) proportional to the normalized power change ($\Delta P/P$) and a frequency transient that is directly proportional to the rate at which the phase or power changes.

5 Overview of chirp measurement methods

Time-resolved chirp measurements require to be modulated with a bit stream to simulate the way in which the device is used in a transmission system. Synchronization must be provided to the measurement system in the form of a trigger signal. Three methods theoretically can provide the same values of $\Delta f(t)$ and $P(t)$. They are the *frequency discriminator*, *frequency-resolved- optical gating (FROG)*, and *monochromator* methods.

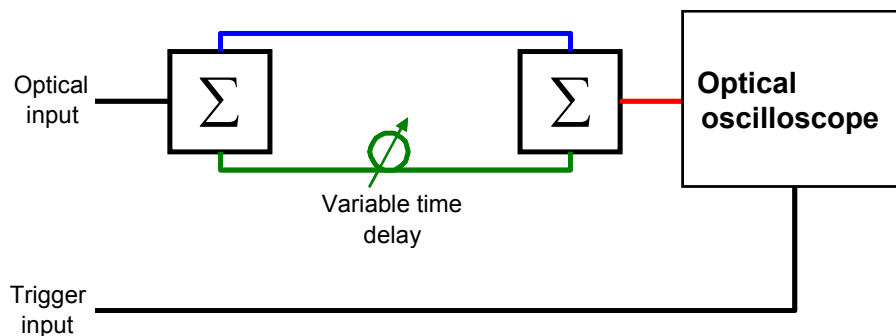


Figure 2 – Simplified diagram for the *frequency discriminator* method

In the *frequency discriminator* method [2][3], a Mach-Zehnder interferometer followed by an optical oscilloscope are typically configured as shown in Figure 10. An optical oscilloscope, sometimes called a digital communications analyser (DCA) consists of a broadband optical-to-electrical converter and a sampling oscilloscope. The differential delay between the two paths creates sinusoidal amplitude versus frequency variation. The frequency spacing is called the free spectral range (FSR). In this method, the interferometer is used to convert frequency deviations into amplitude variation by tuning the interferometer so that the nominal laser frequency is positioned at the quadrature points of the sinusoidal function (Points A and B in Figure 11) and corresponding waveforms are measured on the optical oscilloscope. The optical signal power of the laser transmitter is given by:

$$P(t) = \frac{V_A(t) + V_B(t)}{2} \quad (3)$$

The chirp is calculated by taking the difference of the quadrature waveforms and correcting for the sinusoidal characteristic of the interferometer:

$$V_-(t) = \frac{V_A(t) - V_B(t)}{2} \quad (4)$$

$$\Delta f(t) = \frac{\text{FSR}}{2\pi} \arcsin\left(\frac{V_-(t)}{P(t)}\right) \quad (5)$$