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OAC: Optical line systems
Online course specification

Target audience:
This course is designed for technicians and engineers involved in the design, commissioning and maintenance of optical transmission networks.

Course aim:
This course describes the capabilities, components and operation of the optical links that provide interconnections for telecommunications and cloud service providers.

Course level: Intermediate
An explanation of PTT course levels is given at the end of this document

Pre-requisites:
An understanding of the basic principles of modulation, multiplexing, and optical fibre principles. It is recommended that the PTT online courses "Transmission fundamentals" and "Optical fibre principles" are studied before attempting this course.

Course structure:
The course consists of the following 5 modules:

1. Amplified line systems
2. Maximising link capacity
3. Optical line characteristics
4. Maximising data transfer rates
5. Optical interfaces

Module 1: Amplified line systems

Module aim: To describe the role of the components of various types of optical line system with emphasis on the use of optical amplifiers.

After completing this module, a trainee will be able to:

- give examples of the applications of amplified line systems.
- describe the role of an optical line terminal (OLT).
- explain that wavelength division multiplexing (WDM) can increase the capacity of a unidirectional link and provide bidirectional operation over a single fibre.
- explain that passive optical networks (PONs) in the access network use a combination of bidirectional WDM and time division multiplexing.
- describe and compare the role and operation of SDH terminal mux and OTN muxsponders in optical links.
- state that multiplex equipment such as SDH terminal mux and OTN muxponders incorporate the functions of an optical line terminal.
- explain that optical transport networks (OTN) combine the use of WDM with optical switching.
- describe the benefits of the use of pluggable optics in the interconnection of IP routers.
- explain the principles of optical amplification with reference to the role of erbium doped fibre and the optical pump.
- describe the benefits of employing optical amplifiers in optical links.

- describe the use of optical amplifiers as repeaters, power boosters and pre-amplifiers.

Module 2: Maximising line capacity

Module aim: To describe and compare methods of maximising the capacity of an optical link with particular reference to wavelength division multiplexing (WDM).

After completing this module, a trainee will be able to:

- explain the choice of operating optical wavelength for a particular application.
- describe the function of the various components of a link employing WDM with particular reference to combiners and filters.
- describe and compare the principles, characteristics and applications of LAN WDM, wideband WDM, narrowband WDM, Coarse WDM and Dense WDM.
- describe the role of an optical add/drop multiplexer (OADM).
- explain that employing multi-state modulation techniques can increase the traffic carrying capacity of a link.
- explain the relationship between the maximum number of DWDM channels that can be transmitted through an optical amplifier and the line rate of each channel.
- describe the factors that are taken into account in the design of an optical line system including the required reach, expected traffic loads, and cost.
- explain that special measures have to be taken with DWDM systems to ensure safe working.

Module 3: Optical line characteristics

Module aim: To describe the significance of the various characteristics of optical line system components and the role of the organisations that publish standards for those systems.

After completing this module, a trainee will be able to:

- explain the need for standards for the characteristics and performance of the physical interfaces employed in optical line systems.
- describe the main focus of each of the organisations involved in publishing standards for optical interfaces.
- explain that standards organisations often collaborate in preparing standards for optical systems.
- describe and compare the capabilities of the optical interface classifications as defined by the ITU.
- describe the causes and effects of dispersion with reference to chromatic dispersion and polarisation mode dispersion.
- describe various methods of reducing the effects of dispersion on the performance of a link.
- describe and compare the characteristics of the optical fibres defined in ITU recommendations and IEC standards.
- describe the significance of each of the parameters that determine the performance of an optical line system.
- explain that the use of forward error correction can increase the maximum reach of an optical line.

Module 4: Maximising data transfer rates

Module aim: To explain the techniques that enable ultra-high optical line speeds.

After completing this module, a trainee will be able to:

- describe the role and limitations of on/off keying and direct detection.
- explain the principles and advantages of pulse amplitude modulation (PAM) giving typical applications
- explain the principles and advantages of binary phase shift keying (BPSK) and differential PSK (DPSK).
- explain the principles and advantages of quadrature phase shift keying (QPSK).
- explain the principles and advantages of quadrature amplitude modulation (QAM).
- describe the principles, advantages, and applications of coherent detection in optical systems.
- describe the functions of the elements of a coherent optical receiver.
- describe the principles and role of polarisation multiplexing as a method of providing enhanced data transfer rates.
- describe the principles and role of inverse multiplexing as a method of providing enhanced data transfer rates.
- compare the characteristics, performance, benefits, and applications of various types of modulation system.

Module 5: Optical interfaces

Module aim: To describe the various types of SDH, OTN, and Ethernet optical interface as employed in wide area networks in terms of their characteristics and capabilities.

After completing this module, a trainee will be able to:

- explain that the ITU has specified interfaces for the five interface classifications and aggregate bit rates for SDH networks from 155 Mbit/s to 40 Gbit/s.
- explain that the ITU recommendation G.691 describes SDH line systems that use optical amplifiers for post and pre-amplification.
- explain that the ITU has specified interfaces for the various interface classifications and aggregate bit rates for optical transport networks (OTNs) from 2.5 Gbit/s to 100 Gbit/s.
- explain that the ITU has published standards for single optical channel systems, multi-channel (CWDM and DWDM) systems and those with and without optical amplifiers.
- explain how the nomenclature employed by the ITU for SDH and OTN optical interfaces identifies the attributes of those interfaces.
- describe and compare the capabilities and applications of the IEEE Ethernet optical interfaces operating at 10 Gbit/s to 400 Gbit/s.
- describe and compare the capabilities and applications of the 400ZR, OpenZR+, and Open ROADM optical line interfaces.
- describe the role, capabilities, and functions of pluggable optics with reference to the characteristics required for their use in data centres.
- explain that there are several types of pluggable optics each available for a variety of optical line interfaces .
- compare the role and capabilities of various “Ethernet over SDH” and “Ethernet over OTN” interfaces.

Course access requirements:
To access the course, a computer/tablet running a browser such as Chrome, Safari, Edge etc is required. The device should have an active Internet connection and a screen resolution of at least 1024x768.

Learning facilities:
This online course employs interactive simulations, hypertext links to an online glossary and multiple-choice question sessions to fully involve the trainee in the learning experience. Each module provides revision links to previously studied, relevant topics. A record of progress and level of achievement is recorded for each trainee. Once studied as a structured, assessed course, the content can be browsed for revision or reference.

PTT course levels:
PTT online courses are categorised by one of three levels according to the depth of treatment they provide:

1. **Introductory:**

   PTT Introductory courses are designed for those with no previous experience or knowledge of telecommunications. These courses provide an overview of telecommunications or discuss the fundamentals of electronic communications. The study of general science at secondary (high) school is a typical pre-requisite for PTT Introductory courses.
   PTT Introductory courses are suitable for those joining the telecommunications sector particularly those in an apprenticeship programme.

2. **Intermediate:**

   PTT Intermediate courses are designed for technicians and engineers requiring an understanding of a certain aspect of digital technology. Those planning to study an Intermediate course should understand the basic principles of computing or electronic communications.
   The depth of treatment provided by Intermediate courses is typically equivalent to level 3 of a UK national vocational qualification (NVQ).
   PTT Intermediate courses can be used to support level 3 digital apprenticeships.

3. **Advanced:**

   PTT Advanced courses are designed for those who require an in-depth treatment of a certain aspect of telecommunications. Such courses are suitable for system designers as well as those who will be responsible for the maintenance of the system described in the course.
   Those planning to study a PTT Advanced course should have a background in telecommunications, and an understanding of telecommunications fundamentals and the principles of the type of telecommunications system described in the course.

PTT
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