

**Course****SDH Transmission Systems****Stefano Bregni**

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**Introduction to the Subject**

Beginning with the '70s, the Plesiochronous Digital Hierarchy (PDH) has been introduced and widely used in telephone networks, according to international standards defined by the International Telecommunications Union - Telecommunications sector (ITU-T). The PDH standard defines a hierarchy of digital signals, based on asynchronous digital multiplexing. In the European version, standard bit rates are 2.048 Mbit/s, 8.448 Mbit/s, 34.368 Mbit/s, 139.264 Mbit/s and 564.992 Mbit/s.

In late '80s, the ITU-T defined the new digital transmission standard named Synchronous Digital Hierarchy (SDH), based on the USA standard Synchronous Optical NETWORK (SONET). Standard bit rates of SDH are 155.520 Mbit/s, 622.080 Mbit/s, 2.488320 Gbit/s, 9.953280 Gbit/s and above. SDH was designed using multiplexing and justification techniques that are rather complex, but flexible, to allow synchronous multiplexing of plesiochronous tributaries.

The SDH technique features numerous accessory functions and advantages, beginning with its very high transmission capacity. Today, SDH has replaced most PDH systems, except in some radio relay systems. High capacity SDH backbone networks are the transmission infrastructure not only of legacy telephone networks, but also of packet-switched broadband networks (ATM, IP). Newer developments of SDH, namely Virtual Concatenation (VCAT) and Link Capacity Adjustment Scheme (LCAS), further enhance its flexibility and capabilities, and make it the transmission technology of choice also for high-speed data transport networks.

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**Biography of the Lecturer**

Stefano Bregni is Associate Professor at Politecnico di Milano, where he teaches telecommunications networks and transmission networks. He was born in Milano, Italy, in 1965. In 1990, he graduated in telecommunications engineering at Politecnico di Milano. Since 1991 and for several years, he worked in industry on SDH systems and synchronization networks, first with SIRTI S.p.A (1991-1993) and then with CEFRIEL consortium (1994-1999). In 1999, he joined Politecnico di Milano as tenured Assistant Professor.

He has been Senior Member of the IEEE since 1999. He is Distinguished Lecturer of the IEEE Communications Society. He holds several important responsibilities in the IEEE Communications Society, namely Director of Education, Chair of the Transmission, Access and Optical Systems (TAOS) Technical Committee, and others. He is Symposia Chair of IEEE GLOBECOM 2009 and Symposium Chair in six other IEEE GLOBECOM/ICC conferences. He is Associate Editor of IEEE

Communications Surveys and Tutorials. He was appointed tutorial lecturer in four IEEE GLOBECOM/ICC conferences. He served on ETSI and ITU-T technical committees on digital network synchronization.

He is author of about 70 technical papers, mostly in IEEE conferences and journals, and of the two books *Synchronization of Digital Telecommunications Networks* (Chichester, UK: John Wiley & Sons, 2002; translated and published to Russian by MIR Publishers, Moskow, 2003) and *Sistemi di trasmissione PDH e SDH - Multiplazione* (PDH and SDH Transmission Systems – Multiplexing, Milano, Italy: McGraw-Hill, 2004).

Besides his academic activities, he has extensive industrial teaching experience, also at international level. Since 1994, he has been teaching his technical courses repeatedly in many leading industrial companies, including telecommunication equipment manufacturers (e.g., Siemens, Nokia Siemens Networks, Italtel, Selex Communications), deployers (e.g., Sirti) and telecommunications operators (e.g., Omnitel/Vodafone, the Italian GSM operator Wind, MCI-Worldcom). Technical personnel of several other telecommunications operators in Latin America, Middle East and Far East has attended his courses fruitfully.

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## Proposed Length

This course is proposed with optimal length **four or five days**.

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## Intended Audience

This course has been designed primarily for the technical personnel of telecommunications operators, service providers and equipment suppliers. This may include, but not exclusively, PDH/SDH system engineers, network planners, hardware and software designers, engineers in charge of system testing, operation, maintenance and customer support. It is well suited also for marketing and product managers, who need an overview on all aspects of this technology for promoting products effectively.

Not only practitioners or new-to-the job should attend this course, but also senior personnel with expertise in the field will discover several enlightening aspects and will benefit from attending it.

The richness and depth of course topics cover a wide spectrum of practical and theoretical issues. According to the audience background and previous expertise, the course may be tailored to beginners (entry level) or to experts (advanced level).

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## Requirements

For best understanding of course topics, basic knowledge of digital telecommunications (telephone systems, PCM, multiplexing) is recommended.

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## Course Objectives

This tutorial course provides a thorough overview on several topics that are usually not presented in a single book neither in any competing course on PDH and SDH. In particular, the participants will learn:

- all basic concepts, which are necessary to interact with SDH experts or to understand fully the technical documentation of SDH systems;
- basics of optical transmission systems (WDM, OTDM);
- advantages and drawbacks of PDH and SDH systems;
- operation principles of PDH and SDH with emphasis on practical aspects;
- the SDH frame structure, pointer justification mechanism, overhead and multiplexing schemes;
- functions and system-level description of SDH equipment (regenerators, terminal and add-drop multiplexers, digital cross-connects);
- several examples of network applications of SDH equipment;
- SDH networks architectures;
- traffic protection and restoration in SDH networks;
- techniques for broadband data transport over SDH (ATM, IP, VCAT, LCAS, GFP, GbE);
- other aspects relevant to the design and operation of SDH transmission networks, such as SDH network synchronization, management and testing (in laboratory and on field).

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## Key Benefits of Attending This Course

This course comes up from the long-date teaching and working experience of the instructor in this field, both in industry and in academia. It presents a comprehensive and systematic treatise of many aspects of the SDH technique, from most general to very specific ones.

Since 15 years, this course has been given repeatedly in many leading companies, including telecommunication equipment manufacturers (e.g., Siemens, Nokia Siemens Networks, Italtel, Selex Communications), deployers (e.g., Sirti) and telecommunications operators (e.g., Omnitel/Vodafone, the Italian GSM operator Wind, MCI-Worldcom). The varied audience included system engineers, network planners, hardware and software designers, engineers in charge of system testing, operation, maintenance and customer support, and even marketing and product managers. In the last 15 years, the number of persons that attended this course may be estimated well above one thousand.

This course has been designed to start off personnel, with different work experiences, to master quickly all main aspects of SDH. It has been structured to satisfy the expectations of both those with only general knowledge of telecommunications and those who already have some experience of SDH, either theoretical or practical on field.

After having attended this course, participants should be able to:

- interact advisedly with SDH designers and expert market managers;
- understand the technical documentation of SDH systems they operate in their job;
- understand the operation principles of PDH and SDH equipment systems, including such specific aspects as scrambling, physical interfaces, alarming;
- avoid common mistakes in network planning and operation;
- diagnose common network troubles and intervene appropriately to correct faults;
- plan appropriately data transport over SDH (ATM, IP, GFP, Ethernet);
- plan traffic protection and restoration in SDH networks;

- ❑ avoid mistakes in SDH network synchronization;
- ❑ understand basics of SDH network management;
- ❑ apply techniques and practical procedures for SDH system testing, both in laboratory and on field.

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## Outline

- ❑ **Introduction**
- ❑ **Multiplexing**
  - frequency division multiplexing (FDM) and FDM hierarchy
  - analog/digital conversion
  - time division multiplexing (TDM)
    - PCM telephone multiplex
    - synchronous digital multiplexing
  - optical multiplexing (WDM, OTDM)
- ❑ **PDH transmission systems**
  - asynchronous digital multiplexing
  - bit justification
  - frame structure
  - PDH multiplexing hierarchy
  - PDH equipment
  - drawbacks
- ❑ **SDH transmission systems**
  - historical outline
  - ITU-T standards
  - advantages compared to PDH
  - SDH e SONET hierarchical levels
- ❑ **SDH frame structure**
  - ETSI and ITU-T multiplexing schemes
  - multiplexing elements
  - examples of synchronous multiplexing
  - pointer justification
  - concatenation
  - overhead
  - SDH frame for radio systems
  - BIP-*n* codes: bit error rate estimation
- ❑ **Data transport over SDH**
  - overview
  - ATM over SDH
    - ATM basics
    - ITU-T protocol reference model
    - Physical Layer
    - ATM mapping in SDH VCs
  - IP over SDH (Packet over SDH)
    - motivation
    - protocol stack

- beyond STM-16
- Generic Framing Procedure (GFP)
  - overview
  - frame structure
  - client-independent processes
  - client-specific processes: mapping modes
  - GFP mapping in SDH VCs
- Virtual Concatenation and LCAS
- Ethernet over SDH
- **SDH equipment**
  - functional schemes
  - scrambling
  - alarms and alarm states
  - physical interfaces and line systems
  - regenerators
  - Line Terminal Multiplexers, Add Drop Multiplexers (ADM) and application examples
  - Digital Cross Connect (DXC) and application examples
  - radio relay equipment and application examples
- **SDH network architectures**
  - overview
  - traffic protection: line protection, ring protection, restoration in DXC networks
  - applications
- **Synchronization aspects in SDH networks**
  - synchronization in telecommunications
  - timing relationships among digital signals
  - synchronous and asynchronous transport modes
  - jitter and wander
  - causes of jitter and wander in SDH transmission systems
  - network synchronization
  - models and characterization of clocks
- **Testing of SDH equipment and systems**
  - instrumentation
  - testing of SDH equipment
  - testing of SDH systems
- **Basics of SDH network management**
  - general model of Telecommunication Management Network (TMN)
  - TMN functional architecture
  - TMN physical architecture
  - information model
  - SDH network management