

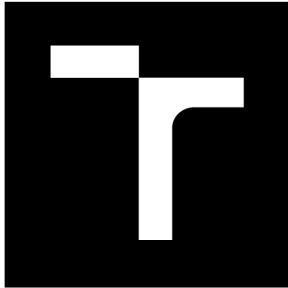
BRNO UNIVERSITY OF TECHNOLOGY

Faculty of Electrical Engineering  
and Communication

BACHELOR'S THESIS

Brno, 2018

Farhad Ab.Jalil



# BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

## FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

FAKULTA ELEKTROTECHNIKY  
A KOMUNIKAČNÍCH TECHNOLOGIÍ

## DEPARTMENT OF TELECOMMUNICATIONS

ÚSTAV TELEKOMUNIKACÍ

## TRANSMITTING TELEVISION SIGNAL VIA FIBER OPTICS

PŘENOS TELEVIZNÍHO SIGNÁLU OPTICKÝM VLÁKNEM

### BACHELOR'S THESIS

BAKALÁŘSKÁ PRÁCE

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TECHNICKÉ A KOMUNIKAČNÍCH  
V BRNĚ TECHNOLOGIÍ

# Bakalářská práce

bakalářský studijní obor **Teleinformatika**  
Ústav telekomunikací

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**NÁZEV TÉMATU:**

## Přenos televizního signálu optickým vláknem

### POKYNY PRO VYPRACOVÁNÍ:

Cílem práce je detailní teoretický rozbor problematiky přenosu kabelové televize (CATV) po optickém vlákně. Důraz bude kladen na problematiku CATV a modulace využívané pro její přenos. Cílem práce bude realizace zapojení přenosu DVB signálu pomocí optického vlákna na vzdálenost několika kilometrů a vyhodnocení kvality přenosu.

### DOPORUČENÁ LITERATURA:

[1] FILKA, Miloslav. Optoelektronika : Pro telekomunikace a informatiku. Vyd. 1. Brno : Centa, 2009. 369 s. ISBN 978-80-86785-14-1.

[2] HARTE, Lawrence. Introduction to cable television (CATV): analog and digital cable television and modems. 2nd ed. Fuquay-Varina, NC: Althos Pub, 2007. ISBN 0972805362.

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*předseda oborové rady*

### UPOZORNĚNÍ:

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# Rozšířený Abstrakt

## Uvod

Telekomunikační systémy se vyvíjejí na rozdíl způsoby. Je pravidlem, že telekomunikační systémy mohou být rozděleny do tří odlišných skupin takto: A) komunita anténa televize (CATV) nebo kabelové TV, B), lokální a velkoplošné počítačové sítě, a C) veřejná telefonní síť switch. Konvergence tří telekomunikačních sítí do širokopásmové sítě pro přenos široký-spektrum zábavy a informačních služeb byl významný nárůst v telekomunikačním průmyslu. Strom a větve širokopásmová síť byla první koaxiální síť, která podpořena RF inovace, ale proto, že kaskády RF zesilovačů, které způsobují snížení kvality a dostupnosti vysílaného amplitudové modulace zbytkovému postrannímu pásmu (AM-VSB) video kanálů a větší nespokojenost zákazníků. Využití mikrovláknových spojů ke snížení dlouhé kaskády zesilovačů RF zlepšil výkon přenosového vysílání analogového videokanál. Když technologie optických vláken, která platila pro kabelové televizní systémy (které jsou uvedeny v širokopásmových sítí) bylo přesně to, co bylo potřeba v té době. Kabelové systémy se rozšiřují své šířky pásma s horní hranicí blížící se 1-GHz. Počet zesilovačů na kabelová míle se zvyšuje na alarmující rychlostí. Vysoká spotřeba energie potřebná další zdroje, což způsobily zvýšené problémy s únikem signál, což všechno vede ke zvýšení nákladů. Byl to opravdu těžký a drahý projekt rozšířit kapacitu pásma a kanálu. Technologie vláknové optiky začalo jako prostě plastových světlovodů působí jako indikátory monitoru pro celou řadu aplikací, včetně automobilů. Pokračující výzkumu v oblasti optiky a optických vláken nakonec vytváří komunikaci z optických vláken. Zavedení 550 MHz přímo modulovaný (DM) poté, co tato externě modulovaných (EM), DFB laserové vysílače a optického přijímače působících na 1310 nm - 1550 nm vlnové délky skupina změnila tradiční architekturu koaxiálních sítí. Zlepšení různých klíčových systémů, jako QAM modulátory a přijímače a MPEG (MPEG) jako digitální video kodérů a dekodérů umožnily provozovatelům kabelových pro přenos televizního signálu prostřednictvím optických vláken. DFB laserové vysílače a optický přijímač působící na 1310 nm - 1550 nm vlnové pásmo změnil tradiční architekturu koaxiálních sítí. Zlepšení různých klíčových systémů, jako QAM modulátory a přijímače a MPEG (MPEG) jako digitální video kodérů a dekodérů umožnily provozovatelům kabelových pro přenos televizního signálu prostřednictvím optických vláken. DFB laserové vysílače a optický přijímač působící na 1310 nm - 1550 nm vlnové pásmo změnil tradiční architekturu koaxiálních sítí. Zlepšení různých klíčových systémů, jako QAM modulátory a přijímače a MPEG (MPEG) jako digitální video kodérů a dekodérů umožnily provozovatelům kabelových pro přenos televizního signálu prostřednictvím optických vláken.

## Popis řešení

Měření v laboratoři se skládá ze dvou částí: 1) Měření a analýza přijatého signálu přes koaxiální kabel. 2) Měření a analýza přijatého signálu přes vláknovou optiku.

- 1) Instalace vertikální (venkovní) polarizace antény Combo (5.1) a Připojení antény k portu RF (IN) HD digitální pozemní přijímač (set Top Box) a propojení mezi Set Top Box a TV, Připojujeme také port RF (Out) portu Set Top Box Spectrum Analyzer.

- 2) Připojení pomocí koaxiálního kabelu od Set Top Box po optický vysílač. Také jsme vytvořili spojení různou délkou vláknové optiky mezi optickým vysílačem a optickým přijímačem. Testování a analýza přijatého signálu přes vlákno Optic jsme připojili optický přijímač k spektrálnímu analyzátoru

## **Shrnutí a Zhodnocení výsledků**

V laboratorních dnech jsme podle našich měření (C / N, Power Signal, Carrier Level, Channel Power) jednoznačně zjistili výhody a nevýhody optických vláken přes koaxiální kabely.

### **Následující popis je výhodou optických vláken přes koaxiální kabely:**

- 1) Výkonné v dálkovém provozu
- 2) Odolnost proti elektromagnetickému rušení
- 3) Menší velikost

### **Nevýhody optických vláken přes koaxiální kabel:**

- 1) Křehkost a hbitost
- 2) Drahé koupit
- 3) Disperze a útlum

## **Abstract**

The main goal of this thesis is theoretical analysis of transmission DVB TV signal via optical fiber, analysis of CATV network and modulation technique used for its transmission. The first part of this thesis is about introduction of propagation of signals in optical fiber and passive components of a fiber optic network, followed by general information about Digital Video Broadcasting, CATV network and modulation format for its transmission. In the second part, which is called practical part, explains our measurement's result, that consists of comparison of different measurement parameters such as "Power SIGNAL", "C/N", "Channel Power" for difference lengths of Fiber Optics.

## **Abstrakt**

Hlavním cílem této práce je teoretická analýza přenosového DVB TV signálu prostřednictvím optických vláken, analýza sítě CATV a modulační techniky pro její přenos. První částí této práce je zavedení šíření signálů v optických vláknech a pasivních součástech optických sítí, následované obecnými informacemi o digitálním rozhlasovém vysílání, síti CATV a modulačním formátu pro jejich přenos. V druhé části, která se nazývá praktická část, vysvětluje výsledek měření, který se skládá ze srovnání různých měřicích parametrů, jako jsou "Power SIGNAL", "C / N", "Kanálový výkon" pro rozdílné délky optických vláken.

## **Keywords**

Fiber Optics, DVB, DVB T2, QAM, HFC, CATV

## **Klíčová slova**

Optická vlákna DVB, DVB T2, QAM, HFC, CATV

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## Declaration

I declare that I have written my Semester Project on the theme of **“Transmitting television signal via fiber optics”** independently, under the guidance of the project supervisor and using the technical literature and other sources of information which are quoted in the project and detailed in the list of literature at the end of the project. As the author of the project I furthermore declare that, as regards the creation of this Semester Project, I have not infringed any copyright. In particular, I have not unlawfully encroached on anyone’s personal and/or ownership rights and I am fully aware of the consequences in the case of breaking Regulation § 11 and the following of the Copyright Act No 121/2000 Sb., and of the rights related to intellectual property right and changes in some Acts (intellectual property Act) and formulated in later regulations, inclusive of the possible consequences resulting from the provisions of Criminal Act No 40/2009 Sb., Section 2, Head VI, Part 4.

**In Brno**.....

**Author**.....

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**Brno**.....

**Author**.....



Vysoké učení technické v Brně

Fakulta elektrotechniky a komunikačních technologií

### **Prohlášení o shodě listinné a elektronické formy semestrální práce**

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Název práce: Přenos televizního signálu optickým vláknem

Akademický rok: 2017/18

Prohlašuji, že elektronická forma odevzdané semestrální práce je shodná s odevzdanou listinnou formou.

V Brně dne 14.12.2017

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Farhad Ab.Jalil

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## INTRODUCTION

Telecommunication systems have been developing in different ways. As a rule, telecommunication systems can be separated into three distinct groups as follows: A) community antenna televisions (CATV) or cable TV, B) local and wide-area computer network, and C) public switch telephone network. Convergence of the three telecommunications networks into a broadband network to transmit a wide-range of entertainment and information services was a significant growth in telecommunication industry. Tree and branch broadband network was the first coaxial network which supported by RF innovation but because cascades of RF amplifiers which cause reduction the quality and accessibility of the transmitted amplitude modulation vestigial sideband (AM-VSB) video channels and increased customer dissatisfaction. The utilization of microwave links to reduce long cascades of RF amplifiers improved the transmission performance of the broadcast analog video channel. When Fiber-optic technology as applied to cable television systems (which are include in broadband network) was just what was needed at that time. Cable systems were expanding their bandwidth with the upper limit approaching 1-GHz. The number of amplifiers per cable-mile was increasing at an alarming rate. High power consumption required more power supplies, which in turn caused increased signal leakage problems, all leading to raise costs. It was indeed a difficult and expensive project to expand bandwidth and channel capacity. Fiber-optic technology started out as simply plastic light pipes acting as monitor indicators for a variety of applications including automobiles. The continued research into the field of optics and optical fibers finally produces fiber-optic communication. The introduction of 550 MHz directly modulated (DM) after that externally modulated (EM), DFB laser transmitters and optical receiver operating in the 1310 nm – 1550 nm wavelength band changed the traditional architecture of coaxial networks. The improvement of various key systems such as QAM modulators and receivers and moving picture expert group (MPEG) as digital video encoders and decoders enabled cable operators to Transmit television signal via fiber optics.

# 1 THEORETICAL PART

## 1.1 Theory of optical communication

Optical communication is a form of telecommunication that uses light as the transmission medium. In optics, the information-bearing signal, digital data signal, CATV RF signal, or cellular channel are up-converted into light frequencies. For instance, 750 MHz-2 GHz is up-converted to a 1550 nm wavelength or 193,548 GHz channel, which carries the signal to its destination, and a receiver, which reduces the message from the received optical signal. In the early 1990s optical power levels were developed, using modulation of the light level of distributed feedback (DFB) lasers with the composite FDM spectrum of signals. Which was equal to that of a 10-amplifier coaxial cascade. However, since optical fibers have a loss that is approximately 1% of the loss of coaxial trunk cable, so telecommunication operators motivated to build larger systems of optical communication, shorter coaxial cascades, wider bandwidths, or some combination of those parameters. As result of the decreasing cost and improving performance of optical technology, decided to make fiber-optic communication for a high-speed and reliable communication. So Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information.

### 1.1.1 Propagation of signals in optical fiber

Transmission over a frequency range of at least 25 THz-even higher with fiber optics, we can have a low-loss and high bandwidth, which is sufficient transmission a million of phone calls at the same time and deliver a million high definition TV (HDTV) video streams which are not available in Copper or any type of transmission media. Transmission with fiber optics we do not forget, still the fiber itself does impose physical limitations that must be taken into account in network design. These fiber transmission limits: loss, nonlinear effects, and dispersion. [3].

We can identify the type of fiber by use of colors on the outer Jacket: Here is

Color	Type of Fiber
Orange	62.5 $\mu\text{m}$ (OM1) or 50 $\mu\text{m}$ (OM2) Multimode Fiber
Yellow	8-10 $\mu\text{m}$ Single-Mode Fiber
Aqua	10 Gbps + Lasers-Optimized 50 $\mu\text{m}$ (OM3) Multi-mode
Blue	Polarization Maintaining single-Mode Fiber

Tab. 1.1: Fiber Color Codes

a relationship between type of fiber design and transmission properties of optical fibers [1] .

In this respect, Two types of fibers are distinguished [1] [7] [8]:

- **Multi-mode Fibers:**

- **A) Multimode fiber:** This type of multimode fiber has a constant refractive index of the core and step refractive of the jacket. This type of Multimode Fibers have a large core diameter (25-60  $\mu\text{m}$ ) and a large NA (Numerical Aperture) one, because of that Light Emitting Diodes (LEDs) can be coupled efficiently into them. differential refractive index is between 1-10 %. A great amount of attenuation (5-20 dB/Km) and dispersion (50 ns/Km) and small transmission capacity at bandwidth of 60 MHz. Mostly used in short-haul links, in particular for automation purposes, short data transmissions, local networks, etc .
- **B) Multimode fiber:** This type of multimode fiber has difference refractive indexes in transversal section of the core. Its cladding radius range of 50-80  $\mu\text{m}$  and has a core radius range is about 10- 35  $\mu\text{m}$ . lower dispersion (1 ns/km) ,lower attenuation (2.5-5 dB/Km) at a wavelength of 0.85  $\mu\text{m}$  and a bandwidth of 600-MHz, mostly used for short-haul links in telecommunication.

- **Single-mode Fibers:** With constant refractive index of the core and step refractive of the jacket, which has low dispersion, very low attenuation, and large transmission capacity, Used in long-haul transmission. Single-mode fibers are the only fibers, which we transmit CATV over it, with small core radius ranging 1-16  $\mu\text{m}$  and dispersion around (0.3 ns/km), attenuation below (0.2 dB/km) at a wavelength of 1.55  $\mu\text{m}$  and a bandwidth of 10-MHz. Differential refractive index between the core and the cladding is about 0.6 %. Single Mode fibers have a narrow acceptance Numerical Aperture (NA), because of that used with lasers. Optical loss in high-quality Single Mode Fiber is caused by Rayleigh Scattering of the silica glass. One of the most significant reason for Rayleigh Scattering is: The inner core of the Single Mode fiber is a composition of glass with a higher refraction index than the outer cladding. Another reason for loss of light inside Single Mode fiber is optical absorption, which results from scattering, the glass impurities due to bend losses and nonconformity inside materials.



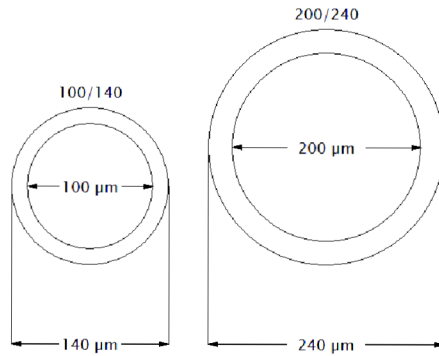


Fig. 1.1: Step-Index Multimode Fibers

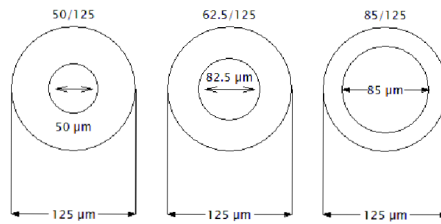


Fig. 1.2: Graded-Index Fibers

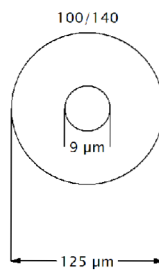


Fig. 1.3: Step-Index Single-Mode Fiber

Different types of Single-Mode Fiber:

- Standard SMF (ITU-T G.652)
- Low Water Peak Fiber (ITU-T G.652 C/D)
- Dispersion Shifted Fiber (ITU-T G.653)
- Low-Loss Fiber (ITU-T G.654)
- Non-Zero Dispersion Shifted Fiber (ITU-T G.655)
- Band Insensitive Fiber (ITU-T G.657)

If we compare Fiber Optics with Coaxial Cable we can easily notice these advantages [7] [8] [9]:

- WDM method:Fiber can transmits several wavelengths, where each wavelength carries wide band data.
- Low loss in Fiber Optics (0.15 db/Km):usually Coaxial Cables loss half of its input power, while this scenario is more less in Fiber Optics: half of input power in every 15-20 Km.
- immunity of Fiber Optics against EMI is more than Coaxial Cables.
- Higher data rates per Fiber Cables and higher data capacity, because Fiber diameter is about 10-50 microns!
- Fiber Optics have large guard band value! In optical communication all signals such as information-bearing signal, digital data signal, cellular channels or CATV RF signals are converted to light frequencies (150 MHz-2 GHz is converted to a 1550 nm wavelength)! The BW for CATV systems is 50-870 MHz to 1560 nm!

## **Attenuation**

Attenuation is defined as the ratio of optical output power to the input power in length of fiber **L** [3] .

wavelength $\lambda$ [nm]	Chromatic dispersion coefficient $D(\lambda)$ [ps · nm <sup>-1</sup> · km <sup>-1</sup> ]
1291-1351	5.7
1311-1371	6.8
1391-1451	11.5
1531-1591	19.9
1471-1611	21.1

Tab. 1.2: Limit values of chromatic dispersion according to ITU-T G.695

Attenuation depends on these three factors [1][3][7]:

- **Absorption:** Absorption of light energy due to heating of ion impurities results in dimming of light at the end of the fiber
- **Radiation:** Due to the Refraction of propagating rays on the interface of dielectric mediums of different properties, when part of the energy escapes out of the core.
- **Dispersion:** The phenomenon means different components of a signal travel at different velocities. Dispersion in most cases limits the data rate of a digital signal by spreading signal pulses over time.
  - **Chromatic Dispersion:** Chromatic dispersion which mostly happens in long-haul single-mode optical fibers is arriving of different colors, or wavelengths, in a light beam to their destination not simultaneously. As a result we will have stretch or flatten the initially sharply-defined binary pulses of information, so it will be difficult to distinguish from each other [3]. Table 1.2 listed the limit values of chromatic dispersion. Chromatic dispersion formed by material and wave-guide dispersion. When the material used to make (usually Silica) fiber optics has a frequently dependent refractive index. That means travelling of different frequency components at different speeds in silica. Also chromatic dispersion arising from wave-guide effects is called wave-guide dispersion.
  - **Inter-modal Dispersion:** Multimode type of optical fiber has a larger core than wavelength of light. This type of Optical Fiber carries a huge amount of modes. These modes act as propagating paths of the Optical signals. While optical signals with variable velocities on these modes, can cause intermodal dispersion. In other hand single-mode type of Optical Fiber, its core's size matches to wavelength of light and cause non intermodal dispersion. This is a significant reason of using single mode fiber optics in long-haul communications.

- **Polarization-Mode Dispersion** Practical optical Fibers are slightly birefringent. when a pulse of light propagate in a fiber, its energy will be split between these two modes, and birefringence cause pulse spreading. This phenomenon is called Polarization-mode-Dispersion (PMD).

## Crosstalk

Effects of other Signals on the designed signal is the concept of crosstalk. Almost all passive component can produce a signal, which can make a crosstalk with another component's signal. Usually there is two types of crosstalk in WDM systems [3]:

- **Interchannel Crosstalk:** When the crosstalk signal is at a wavelength different from the designed signal's wavelength that the difference is larger than the receiver's electrical bandwidth. Variety of sources such as in an optical filter or demultiplexer or in optical switch can produce interchannel crosstalk.
- **IntraChannel Crosstalk:** When the crosstalk signal is at the same wavelength as that of the designed signal or close to it that the difference in wavelength is within the receiver's electrical bandwidth. Reflection in transmission links is a reason of intrachannel crosstalk.

## Nonlinear effects

IF we have a high power and high speed communication for example at 10 Gb/s we have to take care about non-linearity effects. One of the main non-linearity is **scattering**. This phenomenon means, Transmission of energy from one light wave to another wave at longer wavelength (or lower energy),so molecular vibration is the reason for the loss of the energy in the medium. First wave is called (**Pump wave**) as a pumper pumps in the fiber,loses the energy and the second wave which called (**Stokes wave**) gains energy. Usually non-linearity effects divides in two types: **First**-due to interaction of light waves with photons (molecular vibration) in the silica medium. **Second**-due to the dependence of the refractive index on the intensity of the applied electric field. According to first reason,the two most important effects in this category are Stimulated Brillouim Scattering (**SBS**) and Stimulated Raman Scattering (**SRS**).In **SRS** scenario the pump wave is a high-power wave, and the Stokes wave is the signal wave that gets amplifies at the expense of the pump wave. Also according to second reason,the two most important effects in this category are Self-phase Modulation (**SPM**) and Four-wave Mixing (**FWM**). In the case of self-phase modulation, the transmitted pulses undergo chirping, which at high power levels this induced chirp factor becomes more significant[3][1].

- **Self-phase Modulation (SPM):** Different parts of the pulse undergo different phase shifts, because of intensity dependent component of refractive index of fiber optic, thus cause pulse chirping and chromatic dispersion. Pulse chirping has a direct relation with transmitted signal power. At high-bits rate systems we have to more consider this non-linearity effect, because they have significant chromatic dispersion limitations [3].
- **Four-wave Mixing (FWM):** Wave-length division multiplexing (WDM) systems which are using the angular frequencies  $\omega_1 \dots \omega_n$ , the intensity dependent of refractive index not only induce the phase shift but also gives arise to signals at different frequencies  $2\omega_i - \omega_j$  and  $\omega_i + \omega_j - \omega_k$ , so it called Four-wave Mixing . FWM has a inverse relation with channel spacing and chromatic dispersion.
- **Cross phase Modulation (XPM):** Is a nonlinear optical effect, a wavelength of light can affect the phase of another wavelength of light through the optical Kerr effect (change in the refractive index of a material in response to an applied electric field.).[3].

### 1.1.2 Passive Components

#### Connectors

The optical Fiber connector is used to connect and disconnect between a WDM receiver and an ITR (Integrated Triplexer) to the curb (ITC) pigtail to the fiber, and between digital transmitter and receiver to the fiber. The main design goal of connectors are [7]:

- Very low Insertion Loss (0.2dB-0.6dB)
- Have high mechanical reliability without decreasing its reflections, loss performance and mechanical joint locking between connectors.
- Have return loss at range (-43 dB-(-40dB))
- Minimizing the air gap between the two fibers.

Optical connector consists of alignment sleeve and interconnecting pugs. The plug is made of metal or ceramic, which has a hole at its center.

In the field of communications, we have 10 types of Fiver Optic Connectors. These types are more popular: Subscriber Connector (SC), Face Contact (FC), Straight Tip (ST) and SC/APC.

To select an Optical Fiber, we consider following key parameters:

- Insertion Loss  $< 0.5$  dB for CATV.
- Compatibility with other connectors from same type.
- Repeatable over multiple connections/disconnections.
- Better than 40 dB for CAT|V and better than 50 dB for high Gigabit rate.

## Couplers

Couplers are as a splitter and combiner of signals in optical networks. By some methods such as fusion splicing method (joining two optical fibers end-to-end using heat) we can create a  $n \times n$  coupler which consists of  $n$  inputs and  $n$  outputs. According to coupling ratio  $\alpha$  wavelength selective or wavelength independent design of couplers, we can use couplers for many applications in optical networks. For example to deploy a network such as a HFC network use a star coupler. Its primary role is to combine the powers from  $N$  inputs and equally divide them to  $M$  output parts. Star coupler as a independent wavelength is useful in combination of many signals and broadcast them to more than 1 input.  $n \times n$  coupler's power, from each input is divided equally among all the outputs. One of the other usage of couplers is serving as a building block for other optical passive components. A wavelength dependent couplers are widely used to combine signals at 1310 nm and 1550 nm into a single fiber without loss. Usage of Couplers in a Cable TV system is a significant example of typical applications of fiber couplers. In a Cable TV system, transmitter send a powerful signal to a fiber splitter, which broadcast the power on a large number of output fiber. [12][3].

Principles of manufacturing technology of Couplers/Splitter:

- Using Side-Polished Fibers provides access to the fiber core.
- Couplers made from bulk optics which can be fiber pigtailed.
- Planar Line Circuit technology (PLC) based on optical wave-guide chips.
- Fused Biconic Technology (FBC) process provides critical performance and developed polarization maintaining couplers or splitter.

**Splitter:** Splitters as  $1 \times n$  Coupler have ability to divide optical power from one input common port to more split ports and combine all optical power from split ports to one common port. Splitters Usually are referred to by their splitting ratio. Splitting ratio defined as ratio between power output of individual split port by total power output of all split ports [3].

Common Splitter applications include:

- Fiber Protection systems
- CATV Network
- Passive Optical Network (PON)

## Isolators & Circulators

Isolator allow transmission in one direction, by blocking all transmission in the other direction. Insertion loss (1 dB) and Isolation (40 dB) are two limitations for Isolators (circulators). Insertion loss mostly occur in forward direction and Isolation is the

loss in the reverse direction. Insertion loss have to be as small as possible but in the other hand Isolation have to be as large as possible. Isolators are used in optical blocks (Optical Triple Port) modules such as triplexers, Optical dual port modules such as duplexers, laser modules such as thermo-electric DFB lasers [3]. Isolators are divided into two groups:

- Polarization-Sensitive:
- Polarization-Insensitive

Polarization sensitive isolators have higher isolation compares to Polarization Insensitive isolators. The disadvantages of Polarization Sensitive type of isolator is random polarization of the light. The disadvantage Polarization Insensitive isolators are used as a part of the fiber externally to the optical module [9].

The most significant usage of Optical Isolators are:

- Improve optical return loss between fiber and the transmitting laser
- Reduce distortions associated with reflections.

**Optical circulators**, are somewhat similar to isolators but in a difference, which a Circulator has typically 3 ports.

- Input Port
- Reflector Port
- Output port

At normal case a beam of lights enters the input port and exit from the output port, but in the case of reflection due to specific wavelength and an open fiber, beam of lights reflect to the reflected part. [12][3]

## Optical Module

Optical Modules are as a interference between electronics components and Optical Fiber. Their task is connecting the electrical signal to modulated light and a modulated light to an electrical signal in the transmitter and receiver sections respectively. Optical Modules such as Duplexers and Triplexers are as a part of optical Transmitter/Receiver in various applications such as FTTX.

## Multiplexers & Filters

A simple filter is a two-port device that selects one wavelength and rejects all others. It may have an additional third port on which the rejected wavelengths can be obtained. Optical filters use at least in two applications [7].

- To multiplex and demultiplex wavelengths in a WDM systems-these devices are called multiplexers/demultiplexers.
- To provide equalization of the gain and filtering of noise in optical amplifiers.

A multiplexer is a passive component which combines signals at different wavelengths in its input ports onto a common output port. Any demultiplexer can be used in reverse, as a multiplexer. The major difference between multiplexers and demultiplexers is that low interchannel crosstalk is essential for demultiplexers, but irrelevant for multiplexers.

Multiplexing methods is a economical method to transmit data at higher rate on a single fiber. There is two ways to increase the capacity of a fiber.

- Time Division Multiplexing (TDM)
- Wavelength Division Multiplexing (WDM)

**Time Division Multiplexing:** In TDM way interleave many lower-speed data streams into a higher-speed stream. For example, there is some streams, it can pick 1 byte of data from first one, 1 byte from second stream and so on. As an real example, by TDM we can multiplex 64 of 155 Mb/s streams into a single 10 Gb/s stream.

**Wavelength Division Multiplexing:** The concept of this technique is same as Frequency Division Multiplexing, which is used in radio communication. Transmission of data of multiple carrier wavelengths over a fiber. suppose a single fiber looks like as virtual fibers, which each of them are a carrier of a single data stream. As a very simple description. light comes in many different colors, so these different colors can be combined on the same fiber. we can consider a bunch of signals not interference each other. WDM generally has two types:

- Dense WDM (DWDM)
- Coarse WDM (CWDM)
- Cross-band WDM

The only difference between them is the channel spacing. The tighter the WDM channel spacing, the higher the WDM system price. **DWDM** are more useful for long-haul systems. This type of WDM is more tightly packed WDM system and typically is based in the C-band. C-band can has the channel spacing [12][3]:

- 200 GHz-1.6 nm spacing, 20 channels possible
- 100 GHz-0.8 nm spacing, 40 channels possible
- 50 GHz-0.4 nm spacing, 80 channels possible
- 25 GHz-0.2 nm spacing, 160 channels possible

**DWDMs** with following criteria can be implement on fiber:

- Using standard Single-mode fiber (G.652) with no dispersion.
- Not Using intermediate fiber switching device.
- Low Insertion Loss.

**CWDMs:** have 2500 GHz (20 nm) of channel spacing and with this 20 nm of channel spacing approximately 18 channels are available. CWDM transceivers are



significantly less expensive than DWDM transceivers.

CWDM with following criteria can be implement in fiber-link:

- Low Insertion Loss
- Using Stand Single-mode (G.652.c/d)
- Not using intermediate fiber switching devices.

**Cross-band WDM:** Cross-band WDMs are able to combine two channels from different bands inside on fiber. These channels can be from O-band passband (1260-1360 nm) or a C-band passband (1530-1565 nm).

## Optical Amplifiers

The passed optical signals over optic network are attenuated by the optical fiber and other optical components such as multiplexers and couplers. we can amplify these attenuated optical signals by optical amplifiers. Optical Amplifiers increase the intensity of a signal, which have different types for different spectrums of light. Amplification of optical signals is nothing but stimulated emission of radiation by atoms in the presence of an electromagnetic field. This field can be an optical signal in the case of optical amplifiers. According to configuration we can have three types of amplifiers: [3].

- Optical preamplifier: Preamplifier is designed to provide the highest possible sensitivity and high gain in front of a receiver to improve its sensitivity.
- Power Amplifier: Power Amplifier is designed to provide maximum output power and used in front of transmitter to increase the output power.
- Line Amplifier: This type of amplifier is designed to use in the middle of the link.

### **Erbium-Doped Fiber Amplification:**

EDFA (Erbium-Doped fiber amplifier) amplify the low signal power to higher signal power, without any conversion of optic-electric-optic. It is a good choice to use for CATV long-haul transmission systems. An erbium-doped amplifier, which supplied by a silica fiber. The core of this silica fiber is doped with an ionized atom, erbium Er<sup>+3</sup>. When Laser pump a signal, for combination the pumped signal from laser with silica fiber can be used a wavelength-selective coupler at the input, also as same if it is necessary to separate from each other we can use another coupler at the output. Considering a simpler definition, in an EDFA a piece of fiber is doped with Erbium ions. Additional laser power at 980 nm or 1480 nm is pumped via a coupler. The interaction between the Erbium and the pump laser cause the emission of light in the C-band spectrum, amplifying the signal! One of the most advantage of EDFA is capability of amplifying many WDM channels at same time. EDFAs with having a gain bandwidth of about 35 nm in the 1.55  $\mu\text{m}$  wavelength region are

the best choice for CATV systems. According to these characteristics we can use this amplify much more for CATV systems [3]:

- Operates at wavelength of 1550-nm, consistent with C-band where fiber has the lowest loss
- Has higher saturation output power, useful in systems requiring transmission up to 100 km or systems requiring the optical signal to be split to multiple fiber optic receivers.
- The signal gain spectrum is wide up to 30-nm or more, can be used for broad-band signal amplification, especially for WDM (wavelength division multiplexing) system, ideal for radio and data services networks

## Transmitters

Operation of an optical fiber communication system starts at the light transmitter, which converts the electrical signal into optical form and launch the resulting modulated optical signal into the optical fiber. The light source at the transmitting end has to be modulated with message-carrying signal. Lasers as light source used in CATV systems. There are two types of lasers diodes: the **Fabry-Perot** and the **Distributed Feedback** (DFB). One of the biggest limitation for lasers is temperature. Lasers are so sensitive with temperature, because of that in some applications use **Peltier cooler**. The optical transmitter consists of the following components:[3].

- Optical source
- Electrical pulse generator
- Optical modulator

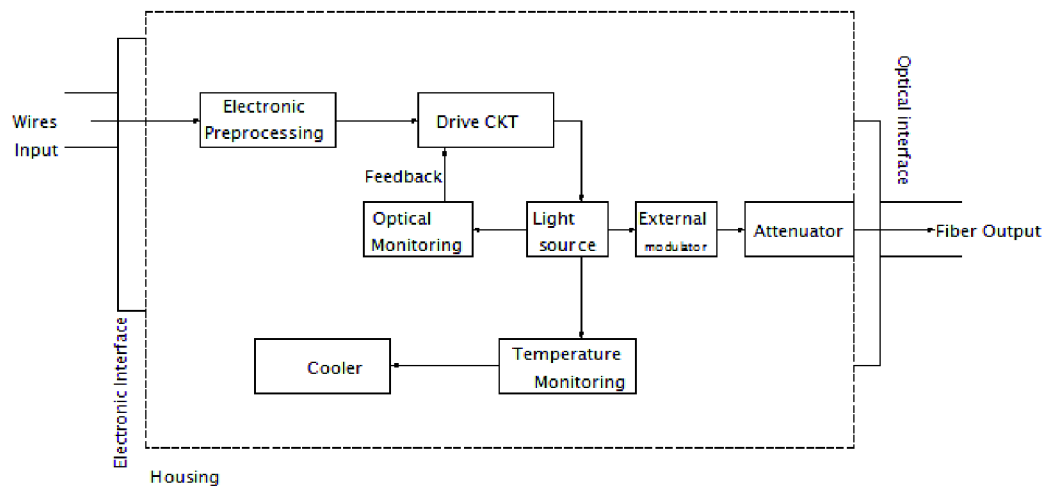


Fig. 1.4: Block diagram of optical transmitter

- **Direct & External Modulation:**

The process of combination of data with the light stream is called modulation. One of the simplest modulation scheme is called on-off keying (OOK). Depending the data bit is 1 or 0, the light stream is turned on and off. We can modulate the data (signal carrier) in one of two ways [4]:

- Direct Modulation of a semiconductor laser or an LED
- Using an External Modulator

**LEDs** have a much wider spectral width, which results fiber dispersion. Dispersion causes the stretching of short pulsed signals in time, which limits the data rates. This is a significant disadvantage but by using different filters reduces the already power level available from LED source and this reduction is proportional to the bandwidth reduction. LED almost usable for short-links and low data rate links. LEDs are made to operate in the 850 nm and 1300 nm regions. LEDs can operate within the temperature range of -25 to +125 Celsius.

**Distributed Feedback Laser or DFB** has lower temperature sensitivity about  $0.08 \text{ nm} \cdot \text{C}^{-1}$ . Their spectral width of the output (10-100 MHz) smaller than the signal spectral width or the wavelength "Chirp" that accompanies the output of these lasers where pulsed. Most lasers diodes in Cable Television are as a package unit mounted in a transmitter with drive circuits and associated stabilization.

In **Direct Modulation (DM)** One of the biggest disadvantage of direct modulation is a chirped output pulse. When The carrier frequency of the transmitted pulse varies with time occur a chirped pulse so causes a broad transmitted spectrum. By increasing the power of a 0 bit can be decrease the the amount of chirping but it reduce the extinction ratio (the ratio of the output powers for the 1 and 0 bits) which in turn, decrease the system performance [4]. In the other hand when use an **external modulator** in front of a light source, turns the light signal on or off based on the data to be transmitted. Here in compare to direct modulator ,the light source itself is continuously operated, where cause the minimizing the undesirable effects of chirped pulse. There is a lot types of external modulator available in industry, which are being integrated with the laser itself inside a single package to reduce the packaging cost. In fact, transmitter packages consist as a laser (as an light source), an external modulator, and wavelength stabilization circuits.

Because of using Solitons or Return-to-Zero (RZ) modulation, external modulators became useful in communication systems. By using a DFB (Distributed Feedback) lasers as followed two stage external modulator we can obtain RZ modulation, so changing the transmission characteristics and changing the

power of a continuous wave laser are two famous characteristics of an external modulator.

Characteristic	LEDs	Laser Diode
Cost	Low	High
Data rate	Low	High
Distance	Short	Long
Fiber Type	Multimode Fiber	Multi and Single-mode
lifetime	High	Low
Temperature sensitivity	Minor	Significant

Tab. 1.3: comparison of Laser Diode with LEDs

Two types of external modulators are widely used today:

- **Electro-Optical (EO)** modulating (Using lithium Niobate modulators) (Low efficiency).
- **Electro-Absorption (EA)** modulation (smaller modulation bandwidth)

The **lithium niobate modulator** makes use of the Electro-Optic effect, where an applied voltage induces a change in refractive index of the material. The device itself is configured either as a directional coupler or as a Mach-Zhender interferometer (MZI), so it applied a voltage to the coupling region changes its refractive index, which in turn determines how much power is coupled from the input wave-guide 1 to the output wave-guide 1. Compared to a directional coupler, the MZI offers a higher modulation speed for a given drive voltage and provides a higher extinction ratio. For these reasons, it is the more popular configuration. In one state, the signals in the two arms of the MZI are in phase and interfere a constructively and appear at the output. In the other state, applying a voltage causes a  $\pi$  phase shift between the two arms of the MZI, leading to destructive interference and no output signal. These modulators have very good extinction ratios ranging from 15 to 20 dB, and we can control the chirp very precisely.

The EA modulator is an attractive alternative to lithium niobate modulators because it can be fabricated using the same material and techniques used to fabricate semiconductor lasers. This allow an EA modulator to be integrated along with a DFB laser in the same package and results in a very compact, lower-cost solution, compared to using an external lithium niobated modulator. In simple terms, the EA modulator uses a material such that under normal conditions, its band-gap is higher than the photon energy of the incident light signal. This allows the light signal to propagate through. Applying an electric

field to the modulator results in shrinking the band-gap of the material, causing the incident photons to be absorbed by the material. This effect is called the Franz-keldysh effect or the stark effect. The response time of this effect is sufficiently fast to enable us to realize 2.5 Gb/s and 10 Gb/s modulators. The chirp performance of EA modulators, through much better than directly modulated lasers, is not as good as that of lithium niobate MZI modulators. We should consider these parameters to have a good system design for transmitter:

- **Output Power:** Nonlinearities and safety consideration are two factors which limit the output power. Usually output power related to type of transmitter. DFB laser and Optical amplifier put out about 10 dBm and 17 dBm of power respectively.
- **Extinction ration:** The extinction ratio is defined as the ration of the power transmitted when sending 1 bit, P1 to the power transmitted when sending a 0 bit, P0. Extinction ratio has a direct relation with production of penalty at the receiver side. If we reduce the extinction ratio reduces also the difference between the 1 and 0 levels at the receiver, so at the receiver side cause penalty. Usually transmitters have extinction ratio between 10-20.

Relative Intensity Noise (RIN) and wavelength stability and accuracy are also important parameters to have a good system design for transmitter.

- **Optical Receiver:**

Conversion of optical signals back into electronic signals and extracting the data is called Demodulation process. Optical Receiver can receive signals with wavelengths down to C and O bands. At the beginning of transmission, when transmitter start modulating the electronic signal for transmission and around its path over fiber, up to end of transmission, it can receive a lot of noise from optical amplifier and undergo attenuation and dispersion. The transmitted data will be acceptable with a range of Bit Error Rate (BER)  $10^{-9}$ - $10^{-12}$  at receiver part for high-speed communication systems. [3]

According to our Figure 1.2 a Receiver consists of these parts: Photo-detector, Amplifier, Receive Filter, Sampler and Decision Circuit.[3]

A photo-detector detects the optical signal and convert that optical signal to an electrical signal. This quit weak electrical signal can be amplified by an amplifier in the next step. After amplifying the electrical signal, can be filtered by a Receive Filter. Filter designed for minimizing the noise and bit error rate and inter-symbol interference due to pulse spreading. In sampling step where describe us a decision for each of transmitted bits of signal in bit intervals are

0 or 1. Sampling requires because of the bit boundaries should be recovered at the received part or receiver.

A testing method which called the Eye Diagram is useful for goodness testing of a received signal. Suppose a received signal is something like a typical received signal of NRZ modulation, with cutting the waveform from its bit boundaries, and these cuts down pieces are superimposed each other, at the result we can have the diagram, which is a human eye shape, because of this they called it Eye Diagram. An oscilloscope is good choice to show this Eye Diagram. Eye Diagram consist of a vertical opening and a horizontal opening. Vertical opening of an Eye Diagram shows the margin for bit error due to noise, but in other hand the Horizontal opening shows the margin for timing error due to an imperfectly recovered clock.[3][15]

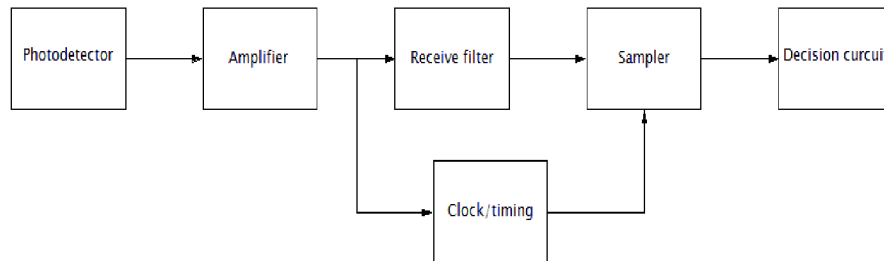


Fig. 1.5: Block diagram showing the various functions involved in a receiver

The two factor key system parameters for a receiver are receiver's sensitivity and its overload parameters [3]:

- Receiver's sensitivity: Average Optical power required to achieve a certain bit error rate at a particular bit rate.
- Overload: Maximum input power that the receiver can accept.

## Detectors

Equally important is that the received optical signal at the receive point must be accurately detected and connects to the cable distribution system. A variety of photo-diodes with a multitude of characteristics have to be considered in making a choice. One of the most important characteristics for a photodiode detector is its responsiveness. This in effect is the sensitivity of the photodiode. Another parameter that is important is the rise time. The rise time is the time it takes for the current to reach its stable values as a sudden increase at light falls on the

diode junction. Pin Diodes- the pin-photodiode does not have the responsiveness so called amplified photo detectors, but it has a very small rise time and can be used for high-speed, high-frequency applications. The pin-photodiode is usually the one used for single-mode operations in cable television optical receivers. Usually, an optical receiver circuit uses an operational amplifier following the pin-photodiode, which does not load the photodiode output and provides some power gain as well as a low impedance output for the following circuitry.[3]

### 1.1.3 WDM Systems

Two more significant advantages of WDM systems are: Transmission as much information as possible through a single optical fiber and flexibility in systems design offers a significant application area of optical fiber systems. WDM systems are able to increase capacity of fiber optic. This increasing is in the frequency domain from one channel to more than 100 channel. WDMs are able to transmit light to all optical protocols such as SONET, SDH, GigE, 10 GigE. We can divide WDM technique into two unique techniques [2][8].

- Wavelength-Selective WDM
- Broadband WDM

**Wavelength-Selective WDM:** Multiplexer at transmitter end combine all source's power and transmit along only one path. While each source operates at a separate wavelength at receiver end with its wavelength-sensitive's characteristics will be separates each wavelength into a different route. Neglecting the insertion loss of the couplers the pout is equal to input power.

**Broadcast-and-Select WDM:** This type of technique use simple splitters and combiner which cause significant power loss in each channel.

Broadcast WDM systems combine all source's power and then divide them at receiver end. Compared to wavelength-Selective systems each transmitter is preassigned a fixed wavelength, all wavelengths are broadcast to all receiver. Each receiver is equipped with filter to separate channels. The divided power is filtered for the desired wavelength, which is then passed to the detector.

WDM consists of two functional side:

- Common Port Side
- Channel Port Side

Common Port Side also known as Network Port, Trunk Port is responsible to connect two WDMs at each end of fiber link. Channel Port side are connected to individual equipment optical transmission and receive fibers.

Four filtering technology are available for WDMs:

- Fiber Bragg Grating (FBG)

- Array Wave-guide Grating (AWG)
- Thin-Film Filter (TFF)
- Diffraction Grating Filter (DF)

Fiber Bragg Grating (FBG) with good filter shape, which used with Circulator increase WDM size and cost. Array wave guide Gratings (AWG) with good filter response, which are the best choice for larger counts. Thin-Film Filter (TFF) with good filter response and low cost are used for WDMs with less than 40 channels.

**NOTE:** Short length of fiber with a periodic change in its refractive index know as a Grating.

Fiber Bragg Grating (FBG) Technology's characteristics:

- Low insertion Loss
- Low temperature sensitivity
- FBGs are completely passive
- FBGs are sensitive to strain
- FBG WDMs have channel spacing greater than 50 GHz
- FBGs have higher dispersion
- FBGs can be connected as a WDM or OADM

Array Wave guide Grating Technology's characteristics:

- AWGs have constant insertion loss
- AWGs are very temperature sensitive
- AWG technology is passive
- AWG WDMs have channel spacing of 12.5-200 GHz
- AWG can be connected as WDM or OADM

Thin-Film Filter technology's characteristics:

- TFFs have low insertion loss
- TFFs are low temperature sensitivity
- TFFs are completely passive
- TFF can be connected as WDM or OADM
- TFFs have channel spacing greater than 50 GHz.

Diffraction Grating Filter (DF) Technology's characteristics:

- DFs have low insertion loss
- DFs have low temperature sensitivity
- DFs are completely passive
- DFs connected as a WDM or OADM
- DFs have channel spacing greater or equal to 50 GHz.

#### **Nonlinear Effects on WDM Links:**

- Multisignal fiber links have a negligible effect of Stimulated Raman Scattering.



- Broadband multiplexed links with power level below 20 mW and Selective-wavelength links with power level below a few milliwatts avoid the effect of carrier-induced phase noise.

Carrier-Induced phase noise is changing in the optical phase of one signal due to changes at the power in itself or in other light waves in the link.

- Brillouin Scattering are proportional with power level, not with number of channels in the link.

### **WDM network Design:**

WDM networks provide circuit-switched end-to-end light-path between two nodes which routed through multiple intermediate nodes such as switch and convert wavelengths. WDM Network consists of these elements:

- Optical Line Terminals (OLTs)
- Optical add/drop Multiplexers (OADMs)
- Optical CrossConnects (OXC)
- Amplifier

**Optical Line Terminals:** OLTs are usually located at either end of point-to-point link and used to multiplex and demultiplex multiple wavelengths. OLTs consists of three functional elements:

- Transponders: Adopts the signal coming from a client of the optical network into a signal suitable for use inside the optical network and also support reverse of this function. connecting a signal to wavelength, monitoring the Bit Error Rate (BER) inside an optical network, are most significant functions of transponders.
- Wavelength Multiplexer: Wavelength Multiplexer multiplex and demultiplex by using any of multiplexing technologies such as Arrayed wave-guide gratings, Dielectric thin-film filters or Fiber Bragg gratings.
- Optical Amplifier

**Optical add/drop Multiplexers (OADMs):** OADMs are used to drop locally unnecessary wavelengths and let the others wavelengths to be routed to their destinations. OADM consists of two common fiber port (In-port and Out-port) for single-fiber OADM and 4 common fiber port (In-East,Out-East,In-West,Out-West) for a two-fiber OADM.

- **ROADM:** Re-configurable Optical add-drop Multiplexer (**ROADM**) is a form of OADMs. The only difference between them is remotely switch traffic from a Dense Wavelength Division Multiplexer (DWDM) system at the wavelength layer. This ability of ROADMs cause adding and dropping each wavelength from a transport fiber without the need of conversion of electrical

signal to optical signal E/O and reverse of this scenario. Automatic power balancing and optical level measuring for each channel are the most important advantage of re-configurable OADMs.

**Optical CrossConnects (OXCs):** At general optical crossconnects acts like as OADMs but in more complex and a huge data traffic networks. In more details and OXC provides several functions such as:

- Service Provision: Provision Optical channels in a large network in an automated mode, which supports performing automated patch panel connections instead of manually configurations.
- Protections: OXC is an intelligent element can detects failures inside the network and reroute light-paths around these failures. Because of this capability protect light paths againsts failures such as fiber cuts and equipment disabilities. Wavelength conversion, Multiplexing and Performance Monitoring are also most significant functions for Optical CrossConnects.

## 1.2 Basic standards on digital TV

Transmission of Digital TV is possible by Satellite, Cable and Terrestrial. Each of them has their own characteristics, to learn them we can transmit and receive TV signals.

### 1.2.1 Digital Video Broadcasting by Satellite (DVB-S)

Digital Video Broadcasting by Satellite use the MPEG-2, as compression technique of Video and prepare more transmission's capacity for more receiving television programs. The only difference between this type broadcasting and other types is just using difference Modulation technique. This type of Video Broadcasting use QPSK (Quadrature phase shift keying) as modulation technique.[13]

As mentioned, DVB-S standard for transmission, use MPEG-2 compression method. This type of compression use a frame, which consists in a package with a length of 188 bytes:1 byte for synchronization, 3 bytes for headline, and 184 bytes for of data (video,Audio and data).



Fig. 1.6: MPEG-2 Packet

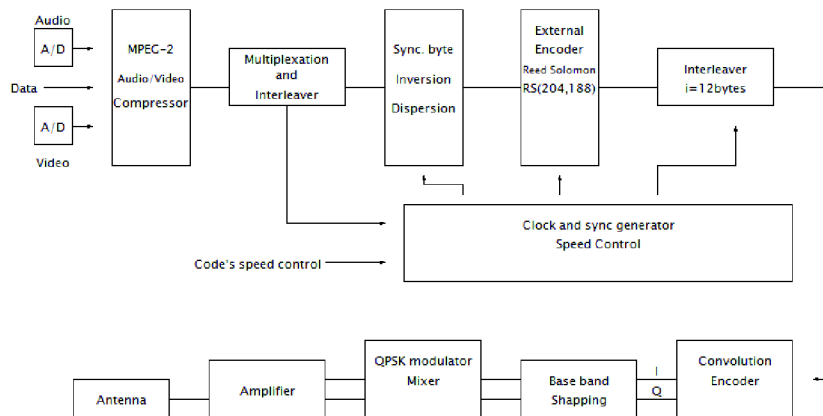


Fig. 1.7: Block of DVB-S standard transmission

### 1.2.2 Digital Video Broadcasting by Cable (DVB-C)

Digital Video Broadcasting by cable (DVB-C) also uses MPEG-2, as compression technique of video but in difference with DVB-S is using QAM (16-QAM, 32-QAM, 64-QAM, 128-QAM also 256-QA) modulation technique. DVB-C is based on European standard ETS 300 429 created for Broadcasting of cable systems. DVB-C with good signal-to-noise (SNR) is useful for any cable networks, which can define modulation and MPEG-2 technique. [5]

#### Technical description of the DVB-C transmitter:[25]

- **Source coding and MPEG-2 multiplexing (MUX):**  
Compressed information streams are multiplexed into MPEG program streams (MPEG-PS's). one or more One or more MPEG-PS's are joined together into an MPEG transport stream (MPEG-TS).
- **External Encoder:**  
By using **non-binary block code, Reed-Solomon RS (204, 188) code** applied to the transmitted data as a first level of error correction.
- **External inter-leaver:**  
Rearrange the transmitted data stream
- **QAM Mapper:**  
Bit stream is mapped into 5 allowed modulation modes: 16-QAM, 32-QAM, 64-QAM, 128-QAM, 256-QAM.
- **Base-band shaping:**  
Filter QAM signal with a raised-cosine shaped filter, cause to remove mutual signal interference at the receiving side.
- **DAC and front-end:**  
For converting Digital signal to Analog Signal, should be installed a D/A con-

verter (DAC). After that by the RF front-end modulate to Radio Frequency.

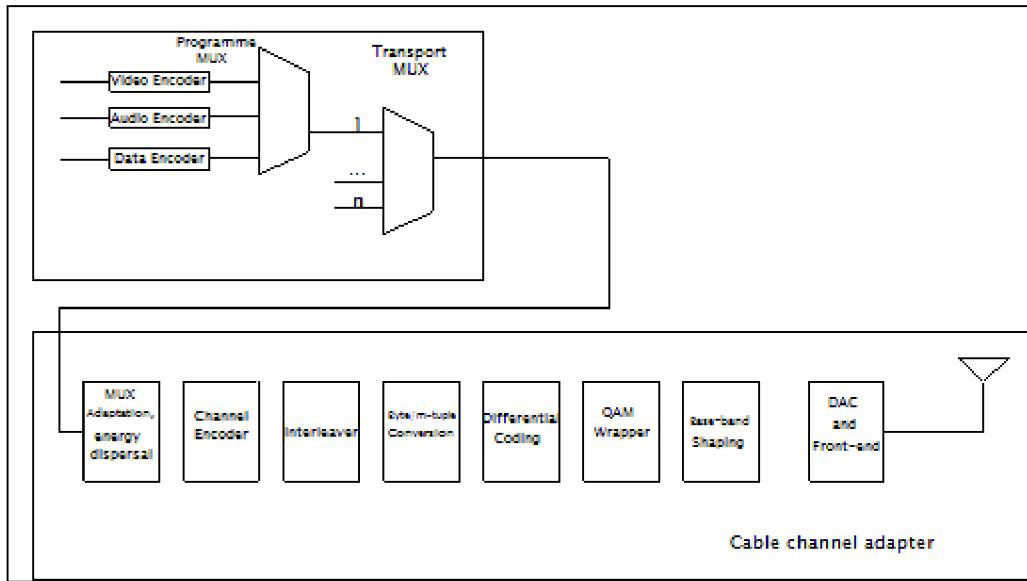


Fig. 1.8: Block Diagram of DVB-C Transmission

New version of DVB-C is called DVB-C2. This standard also useful for CATV systems, in a small apartment or some close to each others. The received signal by satellite and can combine with terrestrial TV signals. [14]

### 1.2.3 Digital Video Broadcasting by Terrestrial (DVB-T)

DVB-T is based on ETSI standard EN 300744 focused to broadcast compressed data with using coded orthogonal frequency-division multiplexing (COFDM or OFDM) modulation and offers three different modulation schemes (QPSK, 16QAM, 64QAM). That is possible just by using enough frequency spectrum. According to user requirements and technical solutions, this type of broadcasting is more complex than other types of broadcasting. In 1990, terrestrial broadcasting had been tested in Digital Audio Broadcasting (DAB) and only in 1998, the first DVB-T network tested in the United Kingdom and after that in other European countries specially in Taiwan and Singapore became operational [23]. system is designed to transmit high-quality of digital information over existing 7-8 MHz channels at rates from 4.98-31.67 Mb/s. Single-Frequency Network (SFN) in Europe was the best reason to use COFDM as a modulation technique.

User requirements for a system for DVB-T:[23]

- All 3-types of broadcasting's system should be similar, because this will ensure the similarity of home receiver for all three broadcasting techniques.
- Transmission of DVB programs should be in data containers and with a large capacity.
- The system should cover a good access area for stationary reception with a rooftop antenna.
- DVB signals should be transmitted in terrestrial single-frequency networks. Single-frequency networks consist of a transmitter, which transmit exactly data streams in synchronize with each other, using the same transmission frequency.

Figure 1.9 shows the Block Diagram of DVB-T system, for channel coding using Forward Error Correction (FEC) and according to modulation scheme use the OFDM or COFDM(orthogonal Frequency Division Multiplex) transmission type. Instead of transmitting one data carrier on a single radio frequency (RF) channel, with this type modulation technique digital data stream can be splitted into a large number of slower digital streams, each of them modulate a set of sub-carrier frequencies. DVB-T has two choices for the number of carriers known as 2K-mode or 8K-mode.

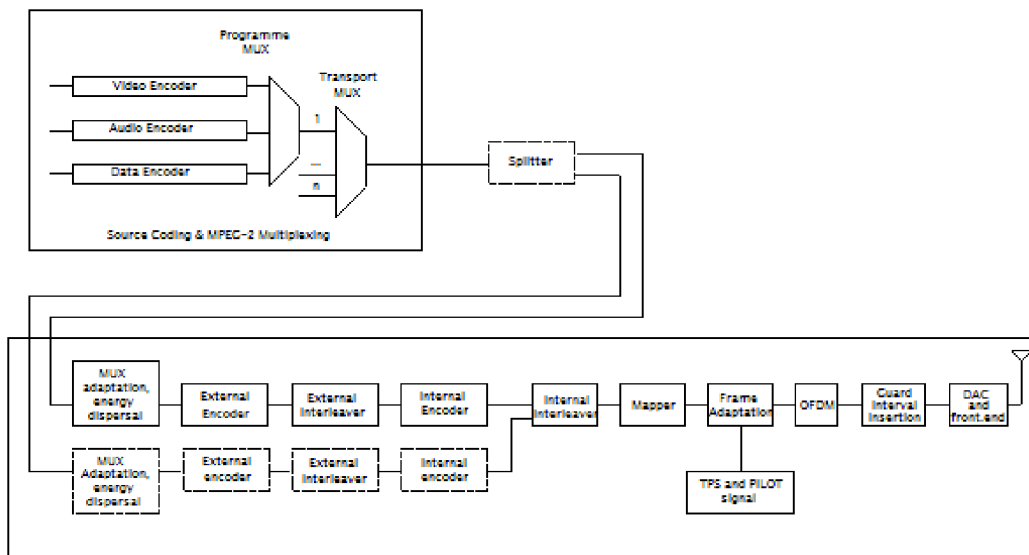


Fig. 1.9: Block Diagram of DVB-T System

#### **Technical description of a DVB-T transmitter:[24]**

- **Source coding and MPEG-2 multiplexing (MUX):**

Compressed information streams are multiplexed into MPEG program streams (MPEG-PS's). one or more One or more MPEG-PS's are joined together into an MPEG transport stream (MPEG-TS).

- **Splitter:**

Two different MPEG-TSs (**Standard definition SDTV signal & High definition HDTV signal**) can be transmitted simultaneously. At receiver part Depends on quality of received signal can be switch one of them.

- **External Encoder:**

By using **non-binary block code, Reed-Solomon RS (204, 188) code** applied to the transmitted data as a first level of error correction.

- **Internal Encoder:**

Applied to the transmitted data as a second level of error correction.

- **Mapper:**

Digital data bits mapped into a modulation scheme: QPSK, 16-QAM, 64-QAM.

- **OFDM Modulation:**

Instead of transmitting one data carrier on a single radio frequency (RF) channel, with this type modulation technique digital data stream can be splitted into a large number of slower digital streams, each of them modulate a set of sub-carrier frequencies.

### **1.2.4 Digital Video Broadcasting-Second Generation Terrestrial (DVB-T2)**

Digital Video Broadcasting-Second Generation Terrestrial (DVB-T2) is the next development of television standard DVB-T. DVB-T2 is also based on ETSI standard and designed for the broadcast transmission of digital terrestrial television. This extension uses OFDM as the basic radio transmission medium with channel coding and interleaving. DVB-T2 with the combination of LDPC (Low-Density Parity Check) coding with BCH (Bose-Chaudhuri-Hocquengham) coding, and compression digital audio, video, and other data in "Physical Layer Pipes" (PLPs), Provide more capacity for HDTV and excellent performance in high-level interference and noise environment.

DVB-T2 systems have more improved efficiency in the use of spectrum (30%-50%) than the DVB-T. Higher spectral efficiency means that with the same amount of spectrum, a larger number of programs can be broadcast or the same number of programs broadcast with a higher audio/video quality or converge quality. coverage

area of transmitter and receiver largely increase while keeping constant characteristics [27][28].

The characteristics of DVB-T2 are the following:

- Higher transmission speed.
- Existing antenna systems can also support DVB-T2.
- The priority is to be multicast on SDTV and HDTV.
- Various protection levels and robustness should be applied on all transported data. For example 8 MHz channel should be able support raftop reception and other reception on portables.
- Could be able to interactive with another services in digital systems and mobile devices.
- Improved Signal Frequency Network (SFN) performance compared to DVB-T.
- Ability to have a mechanism to reduce Peak-To-Average-Power ratio.
- DVB-T2 systems allow for 3 new signal bandwidth: 1.7 MHz, 5 MHz, 10 MHz.
- Flexible frequency and bandwidth.

	<b>DVB-T2</b>
<b>Input Interface</b>	Multiple Transport Stream and GSM
<b>Modes</b>	Variable Coding & Modulation
<b>Forward Error Correction</b>	LDPC + BCH (1/2, 3/5, 2/3, 3/4, 4/5, 5/6)
<b>Modulation</b>	OFDM
<b>Modulation Schemes</b>	QPSK, 16QAM, 64QAM, 256QAM
<b>Discrete Fourier transform</b>	1k, 2k, 4k, 8k, 16k, 32k
<b>Guard Interval</b>	1/4, 19/128, 1/8, 19/256, 1/16, 1/32, 1/128

Tab. 1.4: Comparison of available modes in DVB-T and DVB-T2

<b>DVB-T</b>	<b>DVB-T2</b>
-	1.7 MHz
-	5 MHz
6 MHz	6 MHz
7 MHz	7 MHz
8 MHz	8 MHz
-	10 MHz

Tab. 1.5: Channel bandwidth For DVB-T and DVB-T2

DVB-T	DVB-T2
QPSK	QPSK
16-QAM	16-QAM
64-QAM	64-QAM
-	256-QAM

Tab. 1.6: Modulation schemes for DVB-T and DVB-T2

### 1.3 Network distribution of CATV

With comparison fiber optics with traditional copper lines we can easily find a lot of advantages for Fiber Optics according to copper lines: **1)**-The virtually infinite bandwidth of the fiber lines, which means transmission of a higher data rate capacity and therefore more users per line. With WDM technique we can expand this advantage. Several wavelengths, where carries wide band data through the same fiber. **2)**-low-loss nature of Fiber Optics, traditionally is equal to 0.15 dB/Km , with this advantage less re-transmitting and fewer nodes requires to amplify the signal in fiber optics network.**3)**-fiber diameter of 10-50 is an additional advantage, which one fiber cable can contains many fibers at result higher data rate per cable and higher data capacity. Beginning of Digital broadcasting over cable television and communication satellite digital broadcasting was at same time, then difference transmission schemes have been developed in addition to the standard for broadcasting digital radio-wave broadcast over cable. There have also been changes in the medium used to transmit cable television signals. Currently Cable Television transmit RF signals in the VHF (90 to 222 MHz) and UHF (470 to 770 MHz) bands. Beginning of this technology was transmitted via Coaxial Cable but by introducing of Optical Fiber, this transmission media became the best option to replace with Coaxial Cable. Here is 4 ways for CATV distribution over fiber optics: **A**-All Coaxial Cable. **B**-HFC networks as downstream and Plain Old Telephone Service (POTS) as upstream (Return Path) **C**- FTTx by using WDM technique and PON (Passive Optics Network). Improved Quality, Variety of services are two more significant advantages of FTTX systems in comparison with HFC systems.**D**-Optical-wireless hybrid.[2]

- **All Coaxial-Cable:**The primary network of Cable Television used Coaxial Cable as transmission media for all paths. Because of transmission losses in the coaxial cable, have been used amplifiers every some kilometers. This network replaced with HFC network but most-scale facilities are using All Coaxial-Cable.
- **HFC:** In 1990 established by Telephone and cable companies. Where introduce a lot of services and cost effective products. The primary architecture



was connected between headend to a remote node by fiber optics and from remote node for POTS used coaxial cable. To deliver signals over HFC can be used DOCSIS (DATA Over Cable Service Interface Specifications) protocol, which initiated by Cable Labs.[2]

- **FTTH:** The main difference between HFC and FTTH methods is just the last part media connection. In FTTH instead of coaxial cable use fiber optics. Fiber-To-The-Home or FTTH deliver the data to a living space. Network such as Passive Optical Network (PON) and Point-To-Point Ethernet Network can deliver triple-service over FTTH [2].

The evolution of FTTH started from HFC as we mentioned above a HFC architecture consists of a Head end, where transmit to a node and receiver from a node. Node is a place, where conversion of signals (E/O and O/E) occurs and distribute the service to home by coaxial cables. This enable covering 20-500 homes. Next generation was FTTC, which covered 10-100 homes. The method was implement ion of fiber between CO/OLT and ONUs. Next generation or better to say next step was FTTH, where Central Office (CO) enables transfer the services to homes.

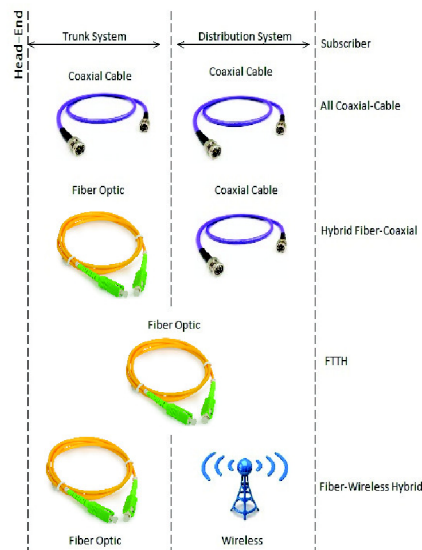


Fig. 1.10: Categories of cable television by transmission media

**Passive Optical Network (PON)** is a (P2MP) point-to-multipoint network topology connecting Central Office and subscriber premises over fiber optic cables. Actually PON is a technology for last mile, which gives opportunity to carry high speed internet voice and video(HDTV). PON uses Passive Splitter rather than an active switcher, because of that PON is much more

cost-effective, compare to PtP Fiber topology. Because of not using power supply, it calls a Passive network [30].

At general, FTTX can carrier CATV data, over 1550 nm and transmits QAM channels and 79AM-VSB channels. Its uplink data of 1550 Mbps over 1310 nm and Downlink at 625 Mbps over 1490 nm.

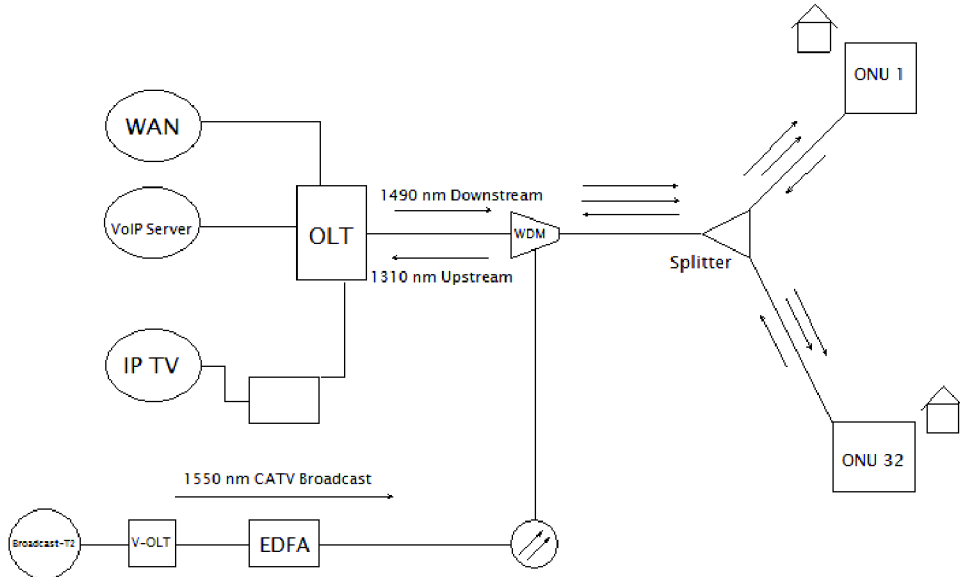


Fig. 1.11: PON With CATV Overlay

### 1.3.1 HFC Network

Increasing the number of users and increasing the requirement bandwidth for internet applications, a new network access needed, which could support all these services. Finally CATV/HFC Community Antenna Television (CATV)/ Hybrid fiber coaxial (HFC) as new network access released. HFC with a Tree-like architecture plays an important role for transmission TV signals to terminals. A TV signal which broadcast by a satellite or terrestrial multiplexed in Central Office (CO) or Primary Hub (PH) and from there transmitted over Fiber Optics (Single-Mode) to secondary and tertiary hubs. Along fiber optics an equipment, which plays an important role in this network is called Optical node. Optical node is nothing but temperature hardened, environmentally sealed containers, where an optical signal convert to an electrical signal for transmission by Coaxial cables, also a place to convert an electrical signal to optical signal for return path transmission. Optical Node can be located every 50km or more. If optical signals directly transmit to home this type of network is called FTTH (Fiber To The Home), but using a coaxial cable to deliver signal to

subscribers we have to use a Distribution Amplifier to amplify the RF signal [18]. HFC/CATV network divide its requirement frequency spectrum for forward path (**54-750**) Which is called **Down-link** and backward path (**5-42 MHz**) which is called **Up-link**. According to nowadays standards a QAM modem located at Central office as a QAM transmitter and followed by QAM receiver at subscriber's places .[16][2][17]

As we mentioned, A HFC network's architecture has Tree-like shape. Generally Consists from a **Backbone** , **primary Hub (Serves 100000)**, **Secondary Hub (25000)** and followed by **Subscribers**. A backbone, where broadcast the signals (Data,Video,Audio) by Terrestrial or Satellite to Primary Hub and from a Primary to some Secondary Hubs and from there transmit by fiber or coaxial to Subscribers. Backbone's network has a Ring-like shape, where uses Synchronous Optical Network (SONET) and also this type of Networking at Primary Hub's stage use Add-Drop Multiplexers to deliver signal to Secondary Hubs.[17]

**Return Path:** In return path, transmitter's responsibility is delivery of POTS (Plain Old Telephone Services) signals and data in upstream! An active terminal sends a BW requirement's message in a upstream frame to head-end. this BW allocation algorithm is variable according to user type, type of service, number of users. Several users(upstream transmission) cause Noise Funnel. To prevent from noise funnel should use a Low-Pass Filter (LPF), which allows 5-15 MHz out [2].

**Building a HFC Network:** HFC Network consists of 3 layers:

- Super link with long distance.
- Supporter link with shorter distance, connect a Super link to Fiber Nodes (performs OE conversion of RF signals to/from Node).
- Doped Link, which connect a Fiber node to subscriber. According to business or campus could be Coaxial or Optic Media.

### 1.3.2 Passive Optical Network (PON):

The distribution network architecture utilized for FTTH and HFC is based on PON architecture and its variants WDM.PON architecture is the most economical broadband optical solution. Three standardized versions of PON:

- **Ethernet PON (EPON):** Using Ethernet in access networks has its advantages. Two of these advantages are more manageable network and making uniform protocol at the customer end. EPON-based FTTH was adopted by IEEE standard (IEEE 802.3) in September of 2004.
- **Broadband PON (BPON):** Using Broadband PON has its advantages. The most two significant advantages are: Reusable ATM infrastructure and the other advantage is providing a third wavelength for video service.

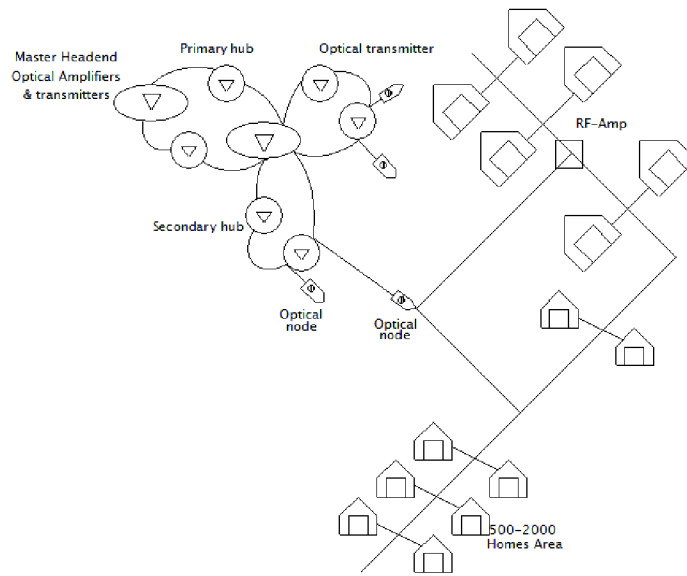


Fig. 1.12: HFC network

Its ITU-T recommendations are G983.2 and G983.2 .

- **Gigabit PON (GPON):** Its ITU-T recommendations are G.984.1, G.984.2 and G.984.3 . The defined functions for BPON reuses in GPON. GPON also can transport multiple services up to 2.5 G/s. GPON technology can support up to 32 subscribers to one port. GPON technology mostly use at high bandwidth demands such as Voice over IP (VoIP), High-Definition Television (HDTV), Media on Demand (MoD) and online Games.
- **Ethernet PON (GEPON/EPON):** GEPON or EPON is an IEEE standard uses Ethernet for sending data. GEPON/EPON uses 1 gigabit per second rates for upstream and downstream. GEPON mostly used in FTTP or FTTH optical network, where one single link is used to serve multiple end-users.

**Advantage of GEPON:**

- Highest availability and density
- GEPON is more cost effective
- GEPON has easier configuration
- GEPON has lots of flexible type of services
- Easy, modular planning and rollout

**Difference between GEPON and GPON:**

- **Operational Speed,**GEPON operates at 2.5 Gbps symmetrical operation while GPON supports 1 Gbps asymmetrical operation.
- **Protocol support,**native Ethernet used by GPON while GEPON is still evolving and supports ATM, Ethernet and WDM protocols.

- **Class of Service (CoS):**Class of Service supported by GEAPON to transport time-sensitive packets such as Video and Voice.
- GEAPON are more flexible and scalable,which provides a lot of services for more than 2300 end-users.

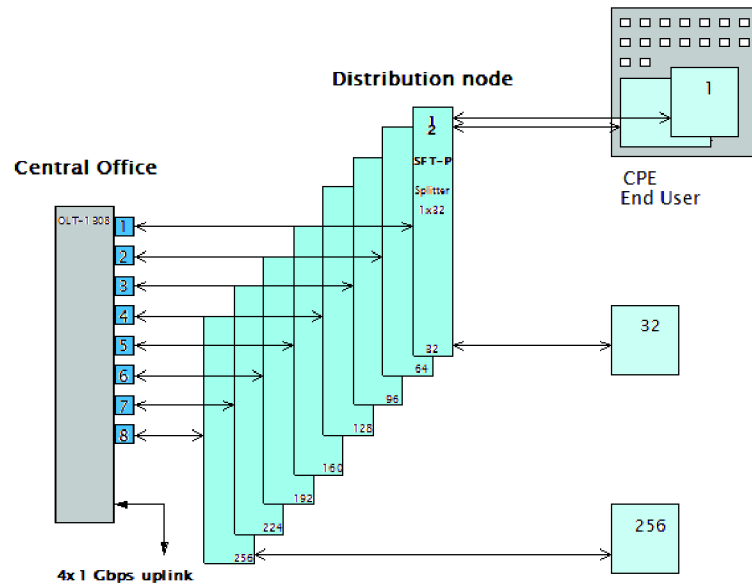


Fig. 1.13: Schematic diagram-GEAPON system

### Implementation of PON:

PON is an Optical -Access architecture that uses passive equipment such as Couplers and Splitters to optically route data traffic between an OLT (Optical Line Terminal) and multiple ONUs (Optical Network Units). PON uses 1310 nm and 1490 nm for wavelengths for data and 1550 nm wavelength for video. A PON can implement as a feeder for broadband Coaxial,Wireless and also can used in FTTX systems. The "X" is location, where the ONUs settle, that can be at the neighborhood, premises, building, the curb and a home. DSL systems are enable with PON, so this is why PON are so attractive. PON allows traditional infrastructure ( Copper, Coaxial, Wireless embeded networks) to be used in shorter but higher BW drops.

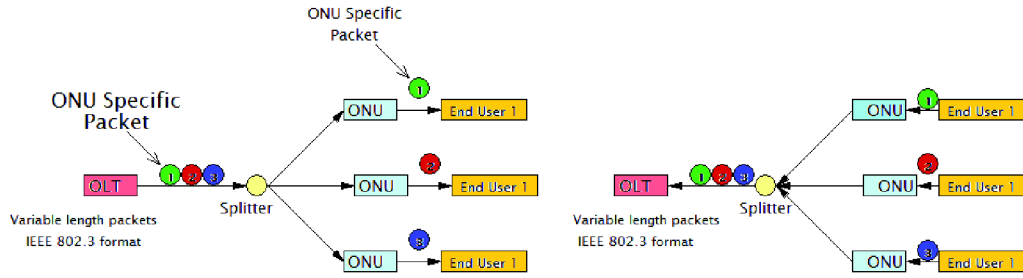


Fig. 1.14: PON-Passive Optical Network functional principles

		Downstream 1490nm	Upstream 1310nm
BPON	Broadband PON	622 Mbit/s	155 Mbit/s
EPON	Ethernet PON	1 Gbit/s	1 Gbit/s
GPON	Gigabit PON	2.5 Gbit/s	1.25 Gbit/s
10G-EPON	10 Gbit/s EPON	10 Gbit/s	1/10 Gbit/s
WDM-PON		No Standard	No Standard

Tab. 1.7: Types of PON

### 1.3.3 Digital video and audio signals compression techniques

#### Digital Video Compression:

A set of standards and file format for Compression of digital Video and audio data. MPEG developed to overcome Bandwidth limitation for digital videos [21]. The two most famous compression method chosen for broadcast television are MPEG-1 and MPEG-2. The Motion Picture Expert Group (MPEG) based on ISO has been activated in video compression standards in 1990s. All MPEG standards are based on following principles:[4]

- MPEG standards do not specify the operation of the encoder, only that of a reference decoder and the syntax of the bitstream that it expects. This allows encoder implementations to improve over time, for example, as better motion compensation search algorithms are developed.
- MPEG standards are a toolbox approach-various features are added from one "Profile" to another, each higher profile adding

complexity and efficiency.

MPEG compression is lossy, which means that the decoded data is not identical to the original. It works with both spatial and time redundancy. Time redundancy is redundanted by utilizing the similarity of beside images. The current slide can be practiced from the previous or next one, that has already been enhanced.

Two types of MPEG, which more useful in broadcasting television signals:

- **MPEG-1 Standard:** MPEG-1 compression method was first method to use in digital satellite and TV broadcasting before MPEG-2 methods. The first version of MPEG-1 compression method introduce for coding of moving pictures and associated audio for digital storage media at up to about 1.5 Mbit/s [2][6]. MPEG-1 method's algorithm developed to improve spectrum efficiency. Reduction of bit rate to store more data and to encode a minimum set of information were the two goal of MPEG-1 compression method [2]!

To store or transmit a TV signal with MPEG-I require to perform a format conversion before encoder and after decoder.

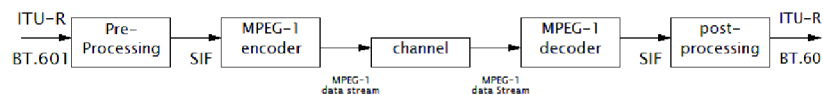


Fig. 1.15: Processing chain in MPEG-1

The typical input format is CIF and the input colorspace is 4:2:0 YCrCb.

The MPEG-I standard specifies the following data units:

- Blocks are 8x8 Pixel
- Macroblocks are 16x16 Pixel
- Slices are subgroups under Macroblocks

- Combination of slices cause formation of pictures which consist of I,P and B pictures types.
- GoP or Groups of Picture are consecutive sequence of pictures. The first picture is always I-Type picture
- **MPEG-2 Standard:** The most appropriate compression method for Digital TV broadcasting is MPEG-2 compression method. MPEG-2 is considered important because it has been chosen as the compression scheme for ATSC (over the-air digital television), DVB (Digital video Broadcasting) and ISDB (Integrated Services Digital Broadcasting), digital satellite TV services like Dish Network, digital cable television signals, SVCD (Service Code Dialing) and DVD (Digital Video) Video [2].

MPEG-2 video compression is popular for a number of reasons:[22]

- There is no limitation for encoder, At result encoder can improve its algorithm to get more compression quality and picture quality.
- MPEG-2 limit the decoder' capability at different profiles and levels. Finally the quality of video can change from one MPEG-2 video decoder to another.
- Defined a lot of standards for transmission and timing function.

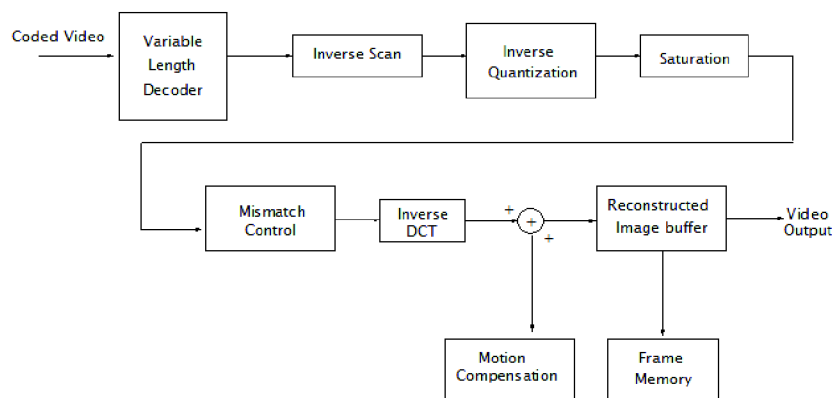


Fig. 1.16: MPEG2 video coding block diagram



## **Digital Audio Compression:**

Compression of Audio signal is more difficult than the video signals. Because in compression of Audio, compression ratios of only 4:1 and 8:1 are achievable in audio, while compression ratio of 30:1 or 50:1 are achievable in video. Two significant methods of audio compression were Dolby AC-3 and MPEG-1 layer 2 [10] [4].

- **MPEG-1 Audio**

**MPEG-1 layer 2** uses 32 sub-bands and codes at 128 Kbps per channel. This technique used in European broadcast applications and Satellite.

**MPEG-1 layer 3** uses 577 sub-band and codes at 64 kbps per channel with same quality as MPEG-1 layer 2. This technique is better known as MP3, which mostly used for "ripping" CDs and also used in portable music player.

- **MPEG-2 Audio**

MPEG-2 audio consist of "Backward Compatible Audio" and "Advance Audio Coding". Backward-Compatible Audio maintain bitstream compatibility same as MPEG-1 with support for 5.1 multichannel audio. Advance Audio Coding "AAC" as advance algorithm increase coding efficiency over MPEG-1 audio. AAC provides 16 low-frequency effects channels, 48 channels for media, 16 data streams and 16 multilingual channels.

## **Digital Audio-Video Transport:**

The previous discussion covered taking individual video and audio feeds and convert them into "Elementary Stream". The next step is combination of all these elementary stream and into a transport stream and decode the digital bitstream for broadcast television.

Some techniques like as ATM "Asynchronous Transfer Mode" enable for each elementary stream to be transmitted at the precise rate. ATM divide the bitstream into fixed 53 bytes cells and allocate them between channels based on their required bit rate.

MPEG-2 system layer defines an ATM-like technique to transmit various components of a digital program in a Multiple Program Transport Stream (MPTS) [29].

- Compressed Audio
- Compressed Video
- Data
- System Information
- Timing Information
- Program related data
- Conditional access information

MPEG-2 system layer uses two ways to multiplex Elementary Stream:

- **Program Stream**-designed for storage-based applications like DVD.
- **Transport Stream**-designed for terrestrial broadcast and Cable systems, which need to constant delay network for transmission.

The MPEG-2 systems transport stream includes the following functions:

- **Packetization**-Encapsulation and segmentation of elementary data streams into 188-byte transport packet.
- **Multiplexing**-a technique for combine compressed audio and video streams into a transport stream.
- **Timing and Synchronization**-Adding and transmission of timing information in transport packets to synchronize as well at receiver side.
- **Conditional Access**-preparation for the transmission of conditional access information in the transport stream.

MPEG-2 transport stream use an error-free transmission path, and so Forward Error Correction (FEC) information must be added to the multiplex before modulation into a carrier signal.

### 1.3.4 Modulation

#### Modulation technology:

Transmission of a stream of bits from a place to another place is the meaning of digital data transmission. Bit, which stands for binary digit, a voltage that can take only two levels or values. We can call these levels 1 and 0. But often in electronic circuits shown by the voltages +3.3 (or +5) and 0 volts. We can transmit these digital data over an RF carrier by modulation of the amplitude, frequency, or phase of the carrier with the information (digital data). We can describe modulation as a process by which a data-bearing base-band signal impresses upon a "carrier" signal, only one base-band signal can be transmitted over one transmission line. Because the second signal can cause interference in same frequency range (Base-band frequencies are set from 0 Hz to the maximum frequency). Modulation process enables occupying different frequency bands by multiple base-band signals through using different Carrier frequencies. Different modulated signals added together to form one composite signal for transmission. This technique called Frequency division multiplexing (FDM). Using the available frequency spectrum on a specific transmission. Many different modulation techniques have been developed with different advantage and disadvantage [10][5].

The following list is classification of different modulation techniques:

- Amplitude modulation schemes.
- Angle modulation schemes composed of:
  - Frequency modulation.
  - Phase modulation.
- Composite modulation schemes composed of:
  - Pulse position modulation.
  - Pulse width modulation.
  - Pulse amplitude modulation.

- Pulse code modulation.
- Delta modulation.
- Phase shift key modulation.
- Frequency shift key modulation.
- Quadrature amplitude modulation.

Because our topic is about CATV over fiber optics we have to select a modulator/demodulator, which provides very good immunity to noise and simple and low in cost and improved in efficiency spectrum. According to these options the most important modulator, which is used in CATV systems is QAM modulator/demodulator. [2]

### **Bit Error Rate:**

The proportion of "number of bits received in error(N.R)" over "total number of bits transmitted(N.T)" is called Bit Error Rate. For example 4 bits are in error for all million bits transmitted then bit error rate is:

$$BER = \frac{N.R}{N.T} = \frac{4}{10^6} = 4 \times 10^{-6} \quad (1.1)$$

Bit Error Rate is proportional with type of modulation, transmission channel's quality and characteristics of modulator and demodulator. one of the most significant method to compare different modulation systems and finding its performance in the presence of noise is to plot Bit Error Rate against the Signal-To-Noise ratio.

### **The Eye Diagram:**

A special oscilloscope display is called an Eye Diagram. Its name comes from its eye-like form. Eye diagram can be used to identify noise and jitters in signal that can ultimately cause errors in data that you transmit. Eye Diagrams are helpful in testing the physical layer fidelity of clock signals in serial data.

### **Spectral Efficiency:**

understanding of spectral efficiency is distinguished of different modulation formats. Spectral Efficiency expressed in bits per hertz: the number of bits per second of data, divided by the RF bandwidth required to transmit it. High spectral efficiency means transmission more bits of data per second in the same number of hertz of RF bandwidth. [4]

### **Amplitude Modulation:**

In amplitude modulation the amplitude of the carrier frequency is a function of amplitude of the modulating signal. Carrier signal has carrier frequency  $f_c$  and modulating signal has modulating frequency  $f_a$ . In practice the modulating signal will be a band of frequency (Commercial speech band one telephony network) [10].

The mathematical description:

$$v_i = [f_a(t) + V_c] \sin(n\omega t) \quad (1.2)$$

$V_c$ ...Peak amplitude of carrier frequency.

$v_i$ ...Instant amplitude of modulated signal.

Instant amplitude of the carrier frequency  $v_c$ :

$$v_c = V_c \times \sin(n\omega t) \quad (1.3)$$

Instant amplitude of modulating frequency  $v_a$ :

$$v_a = f_a(t) \quad (1.4)$$

Because of time dependent of  $[f_a(t) + V_c]$ , the amplitude of the carrier frequency being a function of amplitude of modulating signal.

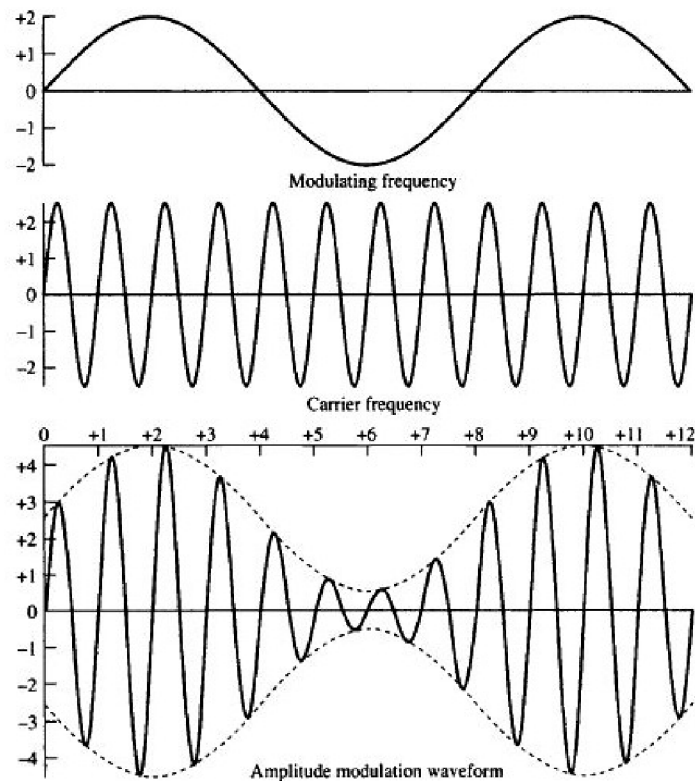


Fig. 1.17: Amplitude Modulation

### Phase Modulation:

In phase modulation, the phase of the carrier frequency is a function of amplitude and frequency of the modulating signal. Larger amplitude of modulating signal causes greater phase change, also higher frequency of modulating signal cause the faster rate of change [10].

$$e = E_0 \sin(\omega_c t + m \sin(\omega_a t)) \quad (1.5)$$

$$e = E_0 \sin(\omega_c t) + \Phi_0 \quad (1.6)$$

$E_0$ ...Peak amplitude of the carrier frequency

$m$ ...Modulation Index

$\Phi$ ...Phase change in carrier frequency

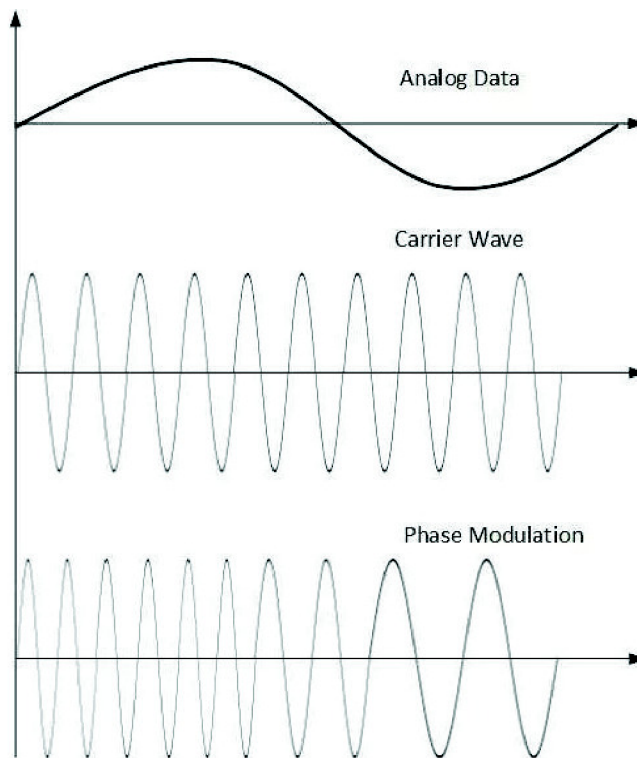


Fig. 1.18: Phase Modulation

### Quadrature Modulators:

According to Figure 1.19 the Block Diagram of a quadrature modulator consists of two mixers and a summation circuit to combine the mixers' output. The input to the mixers are the information bearing BB (low pass) signals  $i(t)$  and  $q(t)$ . A quadrature carrier of the local oscillator (LO) signal  $\cos(\omega_c)$ , mixes with the I input, and  $\sin(\omega_c)$ , mixes with the Q input, where  $r(t)$  is a vector in the I-Q plan.[2]

$$r(t) = i(t)\cos(\omega_c) + jq(t)\sin(\omega_c) \quad (1.7)$$

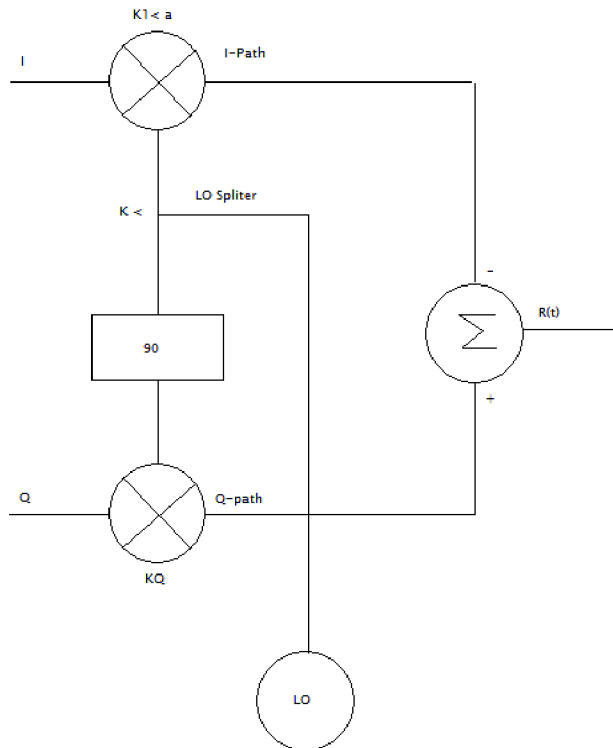


Fig. 1.19: Quadrature modulator

### QPSK:

QPSK (which is QAM without an amplitude component) is a modulation format for the Upstream in cable modem application and also used in DVB-S (Digital Video Broadcasting by Satellite). QPSK modulation format has ability to transmit data over long distance but more noise-resistant and less bit-efficient.

Figure 1.20 shows us QPSK (also called 4-QAM) modulator and demodulator. Input data divided into two channels: I (Input Channel) and Q (Quadrature Channel). Every channel transmits two bits of input data. Each channel of I & Q is modulated onto a carrier. I & Q channels are with same carrier frequency but different in phase ( $90^\circ$  or in Quadrature). These two phases transmit over a common channel without any interference. Each channel have to modulate and after modulation transmit to receiver part. In the beginning of the receiver



located a Phase Locked Loop (PLL). A PLL locks a local oscillator. Received signal through PLL split into quadrature components (I & Q). The splitted signals sent to M3 and M4 demodulators through I and Q channels respectively. finally these signals combined by an encoder to get a Data Stream. A clock recovery circuit reconstructs the clock signal (Type of signal that oscillates between a high and a low state and is utilized to coordinate actions of digital circuits) from the incoming data.[4]

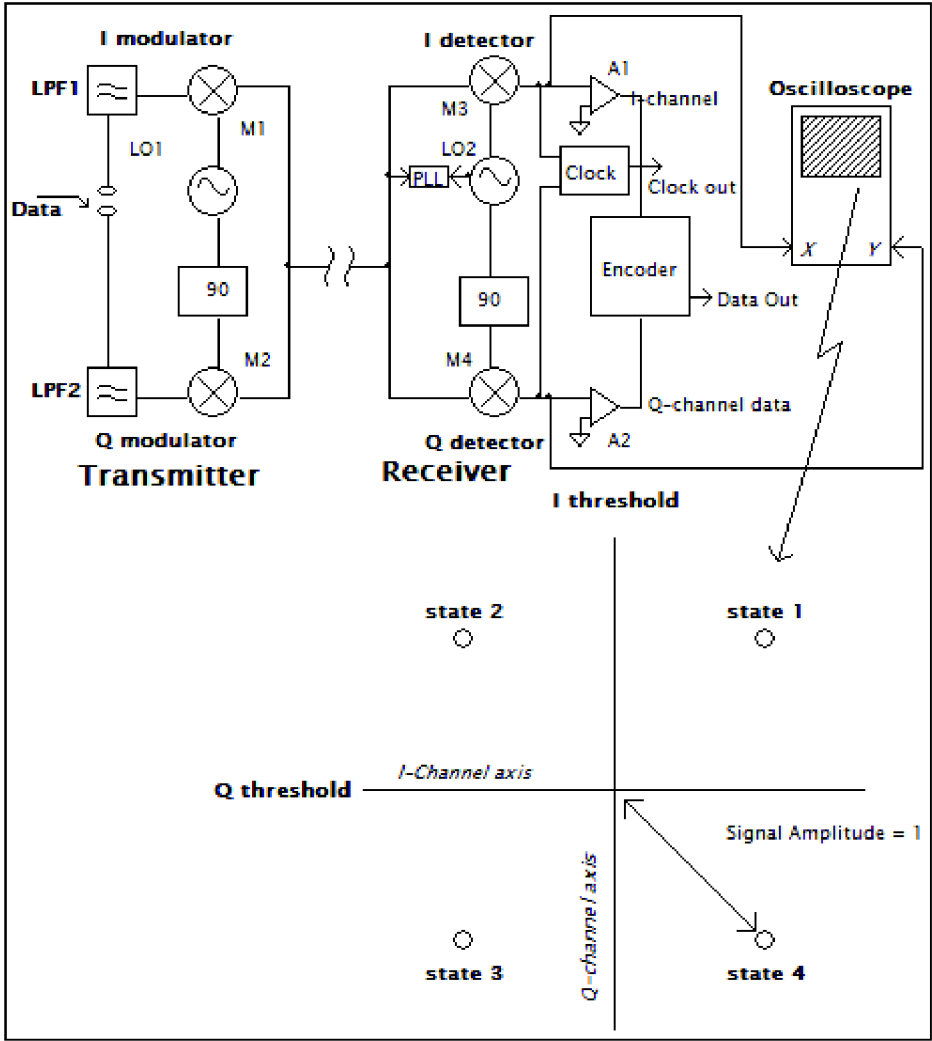


Fig. 1.20: Basic QPSK Modulator and Demodulator

### **The Constellation Diagram:**

The Constellation Diagram is a representation diagram for Modulation formats. This diagram shown by Oscilloscope, Consists of two axis: X-axis, formed by routing the demodulated I signal (each of the 4 or more possible position) and Y-axis, formed by routing the demodulated Q signal (each of the 4 or more possible position). Length of Vector, which originate from origin to any of each possible position says the amplitude of the signal.

The trajectory may pass through several other points as the signal transitions from one point to another in the Constellation Diagram. The comparator for an axis has a signal state at which it makes the decision that the bit represents one value or another. This signal state is defined by the decision threshold. The decision threshold at the comparator will sometimes yield the wrong output. This is due to noise or other channel impairments which results in an error in transmission at the result. To calculate the BER (Bit Error Rate), the probability that any of the points in the Constellation Diagram could interact with a threshold into another state in the Constellation Diagram has to be determined. This results in at least one or more bits being received in error. It is necessary to have the length of the vector from the origin to the furthest point in the Constellation Diagram to show the peak value. In the case of QPSK, all four points have equal distance from the origin. In this case, any of them can be taken as the peak amplitude. It's important to note that the constellation diagram does not represent power but voltage [3][4]!

### **QAM:**

As a general description the combination of digital amplitude and phase modulation is QAM modulation. C.R.Cahn published the first paper about QAM modulation in the name of (AM-PM) systems in

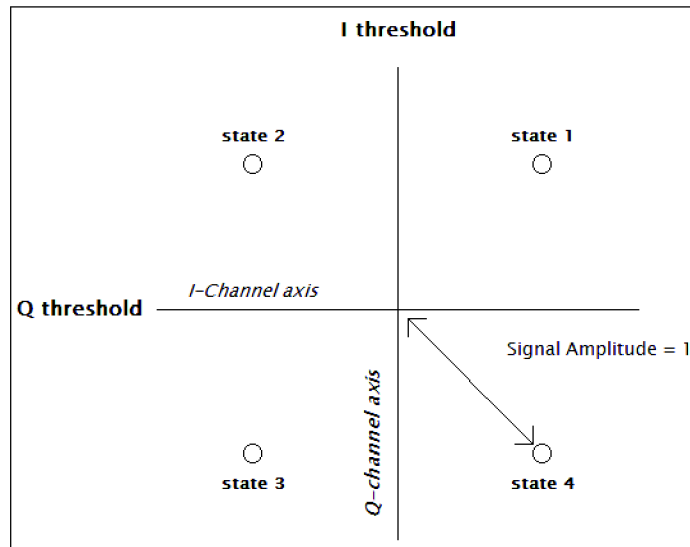


Fig. 1.21: The constellation Diagram

1960. Currently the most highest order constellation of QAM 1024 and 4096 are implemented in wired communication standards. This highest order gives more spectral efficiency, capacity and data throughput.

- **Analog and Digital of QAM:**

QAM Modulation may exist in Analog and Digital versions, Analog version of QAM modulation allows analog signals to be carried on a single carrier. Most famous examples of this analog version of QAM modulation are PAL and NTSC television systems, C-QAM for AM stereo radio. In the other hand digital version of QAM modulation mostly used in data communication and often within radio-communication systems.

- **Advantage of QAM:**

One of the most significant advantage of QAM modulation is having ability to increase the efficiency of transmission by using both phase and amplitude variations.

- **Application:**

The most significant applications of QAM modulation are 64-QAM and 256-QAM in digital cable television and cable modem.

Modulation Format	Application
QPSK	Satellite,CDMA,Cable modems,DVB-S,cable(return path)
8,16 VSB	North American digital TV, broadcast, cable
8PSK	Satellite,aircraft
16 QAM	Microwave digital radio,modems, DVB-C,DVB-T
32 QAM	Terrestrial microwave,DVB-T
64 QAM	DVB-C,modems,broadband set top boxes, MMDS
256 QAM	Modems,DVB-C(Europe),Digital Video(US)

Tab. 1.8: Modulation Formats and Applications

- **Mathematical Model:**

In general a modulated signal can be represented by:

$$s(t) = \sqrt{\frac{2E_{min}}{T_s}} a_i \times \cos(2\pi f_c t) + \sqrt{\frac{2E_{min}}{T_s}} b_i \times \sin(2\pi f_c t) \quad (1.8)$$

$E_{min}$ ....Energy of the signal with the lowest amplitude.

$a_i, b_i$ ....Independent integers chosen according to location of particular signal part.

- **Bandwidth Efficiency:**

We can calculate capacity of a system using each proposed density of QAM by Shannon Formula:

$$C = B \times \log_2\left(1 + \frac{P}{N_o B}\right) = B \times \log_2\left(1 + \frac{S}{N}\right) \quad [bit/s] \quad (1.9)$$

The Shannon bound can be expressed as bandwidth efficiency  $\eta=C/B$  by:

$$\eta = \log_2\left(1 + \frac{S}{N}\right) \quad [bits/s.Hz] \quad (1.10)$$

$C$ ....is the maximum achievable error-free transfer rate of idealized information radio-communication system using optimal coding and modulation,

$B$ ....is the bandwidth of the radio-communication channel,

S.....is the mean value of the signal output at the output of the channel, i.e. at the receiver input,

N.....is the mean noise power at the output of the channel, ie at the receiver input.

QAM Order	Bits/Symbols,K	BW Efficiency(per 20 MHz)
64 QAM	6	120 Mb/s
128 QAM	7	140 Mb/s
256 QAM	8	160 Mb/s
512 QAM	9	180 Mb/s
1024 QAM	10	200 Mb/s
2048 QAM	11	220 Mb/s
4096 QAM	12	240 Mb/s
8192 QAM	13	260 Mb/s

Tab. 1.9: Quadrature Amplitude Modulation Bandwidth Efficiency

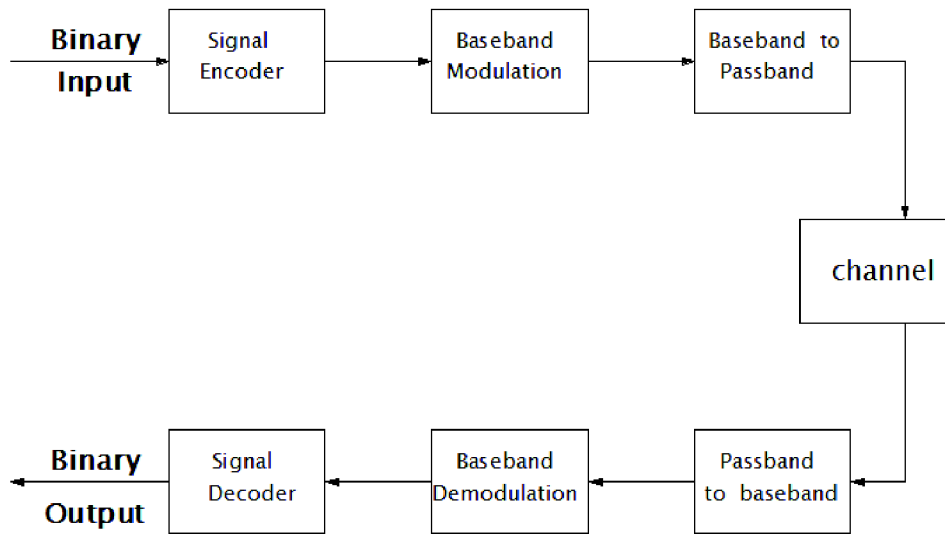


Fig. 1.22: QAM modulator and demodulator

## 16-QAM:

QAM is a technique for broadcasting digital video in most cases for downstream, because in upstream traffic is less noise resistant than QPSK. The Signal-To-Noise (SNR) at the receiver prove this, QAM is more reliable in downstream traffic on a given transmission channel. In comparison to QPSK, Axis in 16-QAM divided in to 4 equally levels, so each channel (I & Q) can transmit just two bits information. Each phase carry two bits, totally become 4 bits per symbol. QAM modulation format define for each symbol value multiple bits. 16-QAM carries 4 bits per symbol while 256-QAM carries 8 bits per symbol. Each channel of the 16-QAM modulator two phases of QPSK also intermediate amplitude values. Data divided into two separate channels but in comparison to QPSK modulation format, each channel simultaneously route two bits together. They are added as shown in Figure 1.23 in the table beside the Q-channel modulator: If two bits are 11(one and one) then adder displays +3 as output with +3 amplitude for Q-channel modulator. If we have two bits for example 10(one and zero) then adder displays +1 as output with +1 amplitude for modulator. according the previous examples 01 data set yields an analog level of -1, which cause 1-level signal with the opposite phase. similarly A 00 data causes -3 to the modulator, which produce a higher-amplitude negative phase signal. Inner levels set +1 & -1, so to maintain equidistant, spacing between levels is 2. In I-channel also happened same things, at results each channel can take on any 4 states. I channel in any of four states with IQ channel independently in any of four states will be have 16 possible states to represents 4 bits of data. According to name of this modulation formats just 16 states of modulated signal are possible. In receiver part, where occur demodulation, have to be so sensitive and processed to recover the two bits data. This is done for the I channel, using the three data slicers shown in figure 1.23. The data slicers have thresholds set by the

four voltage divider resistors, at levels of T1, T2 and T3 [4]. These thresholds shown in constellation diagram at bottom of figure. Decoder can clear the transmitted state by reading outputs of the three comparators (A1-A3). [4]

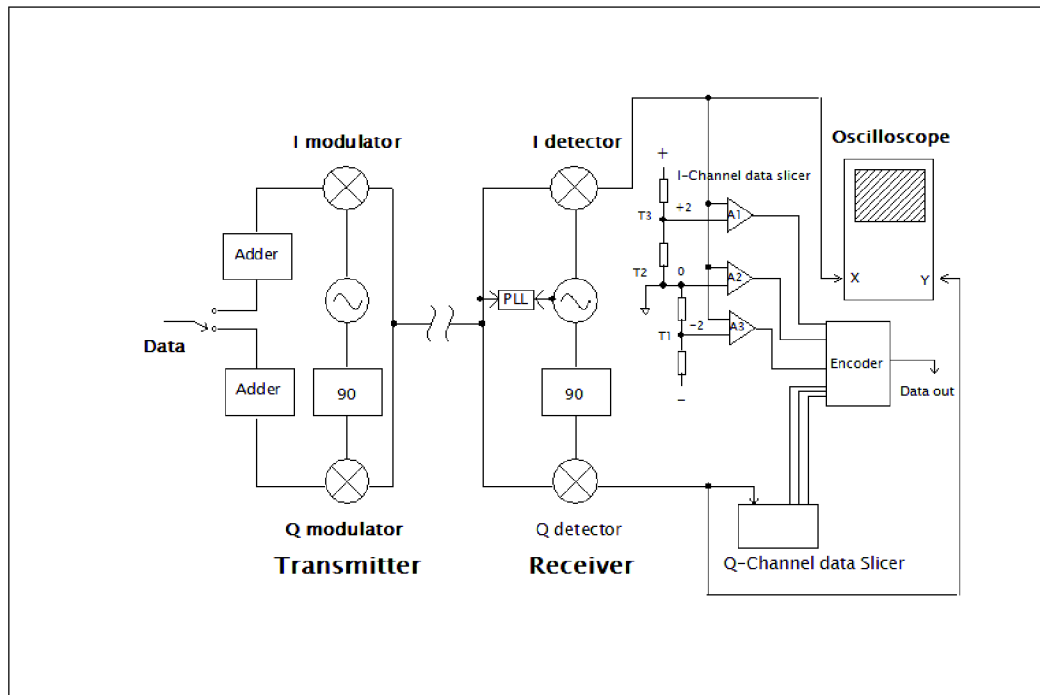


Fig. 1.23: 16-QAM modulator and Demodulator

### 64-and 256-QAM:

In comparison to 16-QAM modulation format, these types of modulation formats have more states (64 states and 256 states for 64-and 256- QAM). Because of more bits of data per symbol, the Constellation Diagram looks like thicker. The disadvantage is short distances between states, so sensitive to distortions of transmission trajectory and noise. Because spectral efficiency is greater, More transmission of data is their advantage [4].

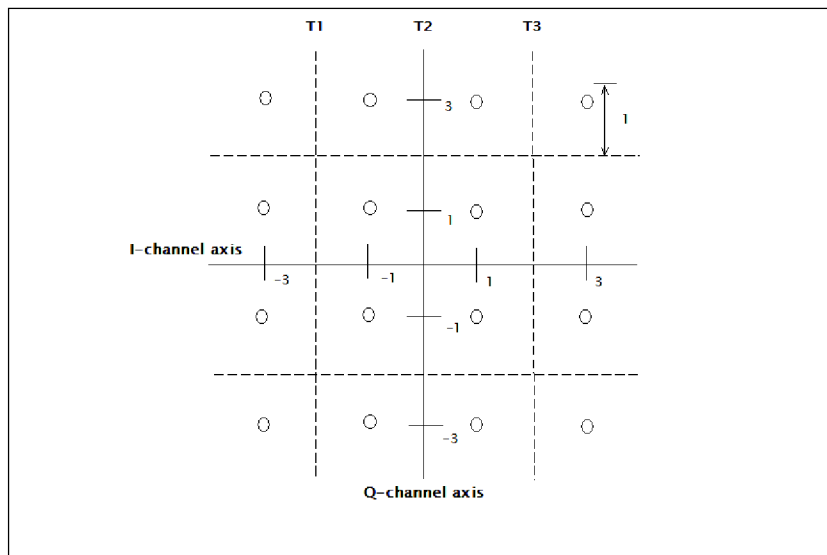


Fig. 1.24: The constellation Diagram of 16-QAM



## 2 PRACTICAL PART

### 2.1 Introduction

Practical part of this thesis consists of 4 parts: First part includes a short introduction, Second part includes our measurements, that explains step by step measurement procedures. Third part includes a brief conclusion from our measurement's results and last part lists measurement equipment with their descriptions.

As we mentioned in theoretical part, one of the most significant advantages of fiber optics is high-quality-Transmitted signal, which received with optical receiver, amplified by optical receiver. Optical receiver has a fundamental role. Optical receiver is an equipment to receive the optical signal and demodulate them to digital electrical signal that can then be processed in any logic circuitry that may be required. The two major important elements in an optical receiver is photo-detector and followed by an amplifier for amplification of electrical signal.

We shouldn't forget the huge amount of light, which passes to optical receiver. Because this huge amount of light can degrade BER and overload the optical receiver. Because of that we used an attenuator with (-10 dB) value. This attenuator is useful to save our optical receiver.

Another useful equipment for our measurement is HD Digital Terrestrial Receiver. We are able to set +5V more voltage to receive higher quality signal.

To test and analysis of TV signal, We measured the useful parameters such as "Power Channel", "Carrier Level", "Power Signal" and "C/N", which are able measured by Televes multimeter and Power Meter FPM.

## 2.2 Measurements

Measurement in laboratory consists of two-parts:

- Measurement and Analyzing received signal over Coaxial Cable.
- Measurement and Analyzing received signal over Fiber Optic.

### 2.2.1 Measurement and Analysis received signal over Coaxial Cable

Measurement and Analyzing TV Signal over Coaxial Cable according to figure 2.1 starts with installing vertical (Outdoor) polarization Antenna Combo (5.1) and Connecting the Antenna to RF(IN)'s port of HD Digital Terrestrial Receiver (set Top Box) and a connection between Set Top Box and TV, Also we connect the RF(Out)'s port of Set Top Box to Spectrum Analyzer. We could search around 54 TV channels with different modulation on difference frequencies, Table (2.1). Following Figure 2.1 shows topology of laboratory measurement:

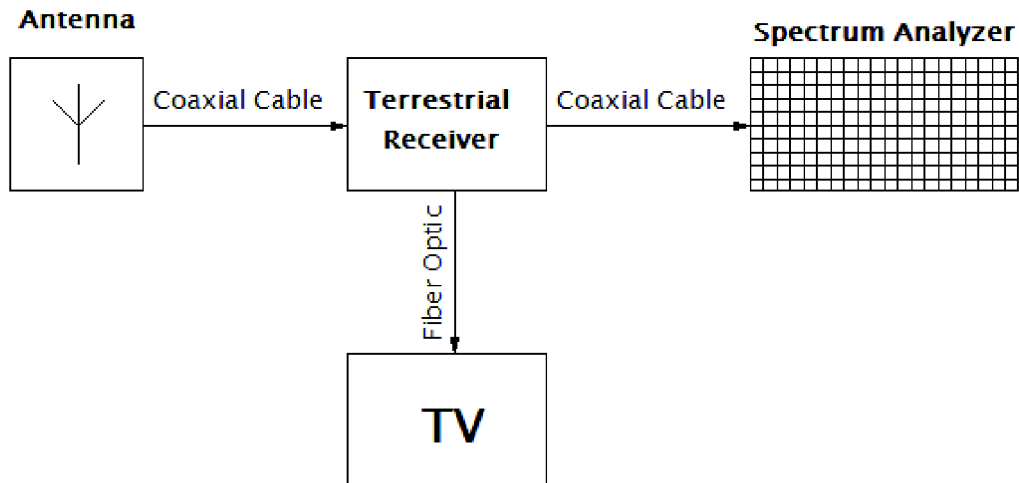


Fig. 2.1: Topology of laboratory measurement

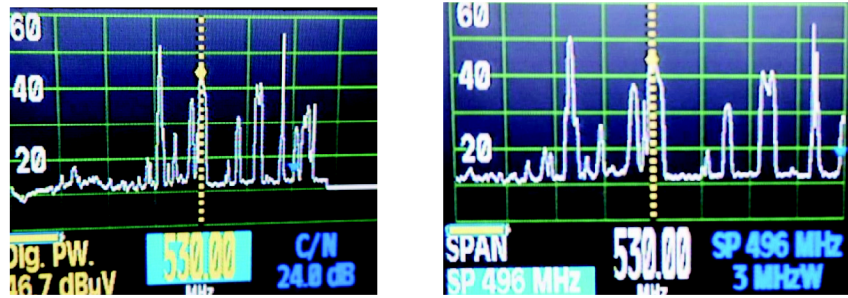


Fig. 2.2: TV signal Over Coaxial Cable in Spectrum analyzer (Borrandov TV)

In this measurement we found the quality of received signal over coaxial cable at different frequencies. Figure 2.2 is a simple of our measurement for TV signal at 530 MHz (Borrandov TV). The received signal over Coaxial Cable is lower than optical fiber. One of the significant parameter for this measurement is measuring C/N. As we know C/N measurement is indication of the quality of a communication channel. According to Figure 2.2 our C/N measurement is about 24.8 dB. If we compare to C/N measurement of received signal over fiber optics, which is proved at Figure 2.11, shows 40.1 dB. We lists the results of C/N measurements for differences channels at Table 2.1. Received signal at 530 MHz over Coaxial cable has  $(43 \text{ dB } \mu\text{V})$ -carrier level (Peak Value). This value is smaller than the received signal over fiber optics  $(100 \text{ dB } \mu\text{V})$ , Which showed at Figure 2.7. As we mentioned in theoretical part, one of the most disadvantage of coaxial cable was transmission losses due to noises. Because of this problem, implemented amplifier on the coaxial cable path every some kilometers, this network replaces with fiber optic. Another disadvantage of coaxial cables is thick volume, it is not easy to install it in intensive monitoring

TV Program	Channel Frequency [MHz]	Modulation Method	C/N [dB]
Brno-TV	506	64 QAM	20.8
Nova Action	674	64 QAM	19.4
CT Sport	538	64 QAM	23.4
Prima Zoom	778	256 QAM	18.5
Borrandov-TV	530	256 QAM	24.0
CT-HD	682	256 QAM	19.4
Prima	628	256 QAM	21.3

Tab. 2.1: Characteristics of Received TV Programs

### 2.2.2 Measurement and Analysis received signal over Fiber Optic

Measurement and analyzing TV signal over Fiber optic according to our topology in Figure 2.3, We made a connection by Coaxial Cable from Set Top Box to Optical Transmitter. We also established a connection by different length of Fiber Optic between Optical Transmitter and Optical Receiver. To test and analyze of received signal over Fiber Optic, we connected Optical Receiver to Spectrum Analyzer. Table (2.2) shows us the power of TV signal before plugging Optical Fiber at Transmitter's side and also the Power of TV signal at Receiver's side of our network.

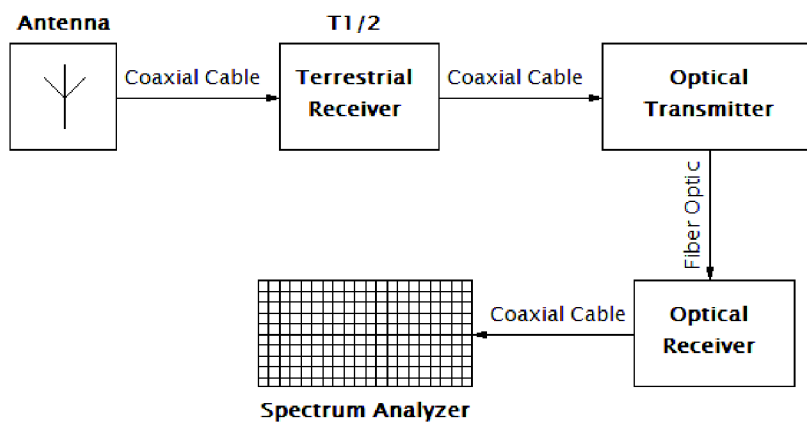


Fig. 2.3: Topology of laboratory measurement

### Analysis CATV signal with Power Meter FPM-600

First of all we started measurement with power measurement of signal (dBm). The measurement established with Power Meter FPM-600 in two stages. **1)** Before connecting optical receiver with optical transmitter, **2)** After connecting optical receiver with optical transmitter with variable lengths of fiber optic.

We used an attenuator at receiver side. Attenuator is useful to save optical receiver from overloading. Because a huge amount of light can degrade BER and overload the optical receiver.

According to our theoretical part for every km of optical fiber we should consider **Fiber Attenuation**(0.23 dB), **Connector Loss**(0.7 dB), but our results table 2.2 shows a little bit more. This is why because of inappropriate connection between equipment.

length [Km]	1.Power [dBm]	2.Power [dBm]	Attenuator [-10]
1	8.17	7.34	-3.34
3	8.19	7.17	-3.17
4.69	8.20	6.9	-3.1
7	8.19	5.31	-4.69
9.15	8.19	3.64	-6.36

Tab. 2.2: Power measurement

### Analysis of CATV signal with Televés Multimeter

The setup consists of 1550 nm external modulation optical transmitter, optical receiver, digital antenna equipped with shielded connectors, cable and integrated filters which is suitable for indoor and outdoor, HD digital terrestrial receiver and Televés series Multimeter. Multimeter Televés series gives us options to measure **Carrier Level**, **C/N**, **BER**(for DVB-T/S but not for DVB-T2), **Channel Power**.

- **Level:** We can measure the carrier level in 2-modes. **1)** channel tuning mode: this function will measure the carrier level of the tuned channel. **2)** frequency tuning mode: this function will measure the carrier level of tuned frequency.
- **C/N:** Carrier-To-Noise ratio is the Signal-To-Noise (SNR) of a modulated signal. In terms of digital communication, digitally modulated signals are usually referred to as carriers. C/N gives us the quality of digitally modulated signals. C/N measured in dB.
- **BER:** The fraction of bits transmitted that are received incorrectly. BER is key parameter that is used in systems such as radio data links, fiber optic data system and Ethernet, which able to transmit digital data from one point to another point. BER has indirect relation with Signal-To-Ratio (SNR). When SNR ratio is high, then the bit error rate will be small. BER in optical fiber system is result from network components such as optical transmitter and optical receiver and the fiber itself. BER may also be introduced as a result of optical attenuation and dispersion.

### **Measurement procedure:**

The following information is about a step by step explanation about the measurement procedure at laboratory:

- **Band switching**(shortcut button "1"):  
This function allows us switch the band from terrestrial to satellite and vice versa. We selected terrestrial band for our measurement.
- **Standards:**  
This function allows us to select the colour standard. The standards that are available (Figure 2.4):
  - SECAM L: Used only in France.
  - SECAM B/G: Used in Middle East and Greece.
  - PAL I: UK, Hong Kong, Ireland, South Africa.

- **PAL D/K**: Central and Easter Europe.
- **PAL B/G**: Most parts of Western Europe, Australia, New Zeland.

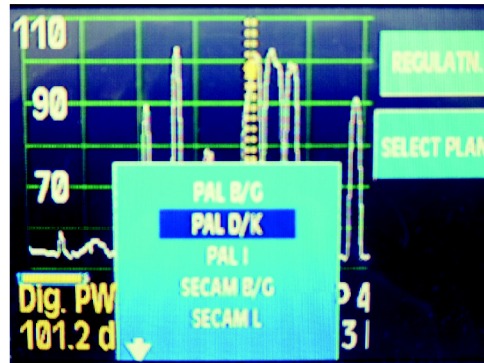


Fig. 2.4: Standard Selection

- **Measurement Window**(shortcut button "4"):
 

This option has an important role during measurement. When this option selected, the last measurement's window opens. If last measurement is about level, so two windows "Abbreviated" and "Extended", opens. Extended window has information in details.
- **Measurement:**

TV Mode consists of "View Mode", "Measure", "Channel Search" and "Select Audio Carrier" .

We need the "Measurement" option. We can vary the tuned frequency as we need and measure them. To enter frequency by keyboard, first we need press the **Freq.** button and type the requested frequency by keyboard.

  - **Channel Power:** We can measure channel power of tuned frequency and tuned channel. Frequency tuning has been selected for our measurement. Selected tuned frequency will be taken as the intermediate frequency of the digital channel.

Channel power's menu has another sub-menu, Bandwidth. User has to select a BW for measurement. The below picture gives us a simple of Power channel measurement of 1-Km fiber optics at 778.30 MHz frequency.

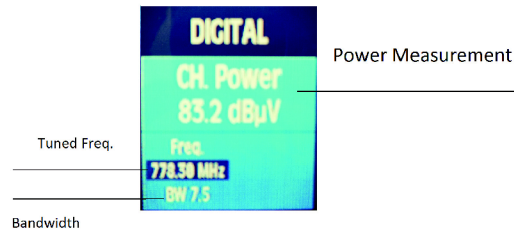


Fig. 2.5: Power Channel measurement

The following tables are results of our Power measurement for difference length of fiber optics at difference frequencies.

Frequency	Power Channel Measurement
503	90.8
530	104.9
680	96.6
778	83

Tab. 2.3: Power Channel measurement of difference frequencies for 1-Km Fiber optics

Frequency	Power Channel Measurement
503	90.3
530	104.1
680	95.9
778	81.5

Tab. 2.4: Power Channel measurement of difference frequencies for 3-Km Fiber optics



Frequency	Power Channel Measurement
503	88.3
530	99.8
680	95.7
778	80.5

Tab. 2.5: Power Channel measurement of difference frequencies for 5-Km Fiber optics

Frequency	Power Channel Measurement
503	87.1
530	99.6
680	90.3
778	75.78

Tab. 2.6: Power Channel measurement of difference frequencies for 7-Km Fiber optics

– **C/N(dB):**

we can measure C/N of tuned channel or tuned frequency. Frequency tuning mode has been selected for our measurement. We have to make sure that is frequency related to the real channel carrier. To carry out this measurement we have to select the reference frequency and channel bandwidth (BW). To do these two parameters, multimeter has two sub-menu. 5 MHz BW has been selected for this measurement. C/N measurement is indication of the quality of a communication channel.

Figure 2.6 gives a simple of C/N measurement of 1-Km fiber optics at 778.30 MHz frequency.

The following Tables are results of our C/N for different length of fiber optics at difference frequencies.

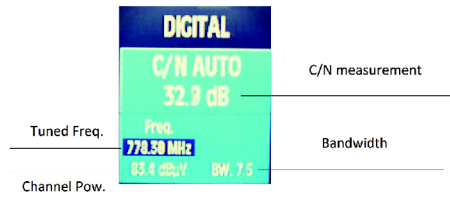


Fig. 2.6: C/N measurement

Frequency [MHz]	C/N Measurement [dB]
503	32.1
530	38.7
680	34.1
778	32.9

Tab. 2.7: C/N measurement of difference frequencies for 1-Km Fiber optics

Frequency [MHz]	C/N Measurement [dB]
503	30.4
530	38.3
680	33.4
778	32.3

Tab. 2.8: C/N measurement of difference frequencies for 3-Km Fiber optics

Frequency [MHz]	C/N Measurement [dB]
503	28.3
530	33.5
680	33.4
778	31.8

Tab. 2.9: C/N measurement of difference frequencies for 5-Km Fiber optics

Frequency [MHz]	C/N Measurement [dB]
503	27.9
530	31.6
680	32.5
778	30.8

Tab. 2.10: C/N measurement of difference frequencies for 7-Km Fiber optics

- **Spectrum Analysis:**

This part of our measurement contains spectrum analyzer mode. We can see the signal spectrum according to used frequency and selected span. The bottom of our screen shows the parameters of measurement.

The below picture gives spectrum analyzer mode of 1-km Fiber Optic.

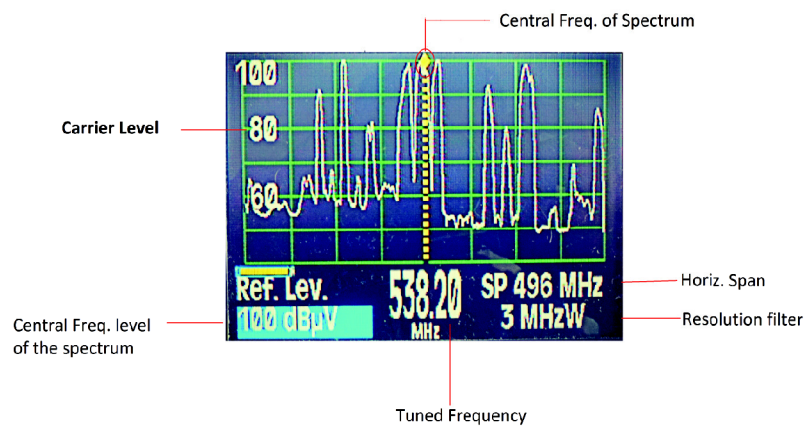


Fig. 2.7: Spectrum Analyzer

Spectrum mod consists of three more sub-menus REF.LEVEL,SPAN and MEASURE, as we can see on following picture:

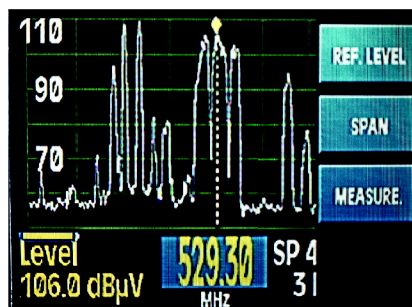


Fig. 2.8: Spectrum mode options

– **Ref.Level:**

We can optimize the view of the spectrum of the signal by setting this level. we can set this value between range of 60-130, which is corresponds to the value of upper horizontal line of spectrum.

– **Span:**

This option allows us change the range of frequencies. The possible values for terrestrial band are: 8,16,32,48,96,192,496 MHz and full span.

– **Measure:**

This function in spectrum is same as measurement in TV mode. During measurement also we can change the frequency and channel. It consists of Digital and Analog measurement.

\* **Measurement:**

This sub-menu consists of Channel Power and Automatic C/N measurements. During the measurement we took difference frequencies for different length of fiber optics (1,3,5 and 7 Km).

· **Channel Power:**

Before everything for this parameter we should select suitable bandwidth. Multimeter takes the tuned frequency to be central frequency of the digital channel. Channel Power's measurement can seen on the lower left-hand. This screen-shot gives us information about measurement for power of digital channel, which is shown on left-hand of screen. Right-hand of screen shows information about Horiz. Span at 496 MHz and Resolution Filter at 3 MHzW. Our results for different lengths of fiber optic at different frequencies was same as tables 2.3,2.4,2.5 and 2.6

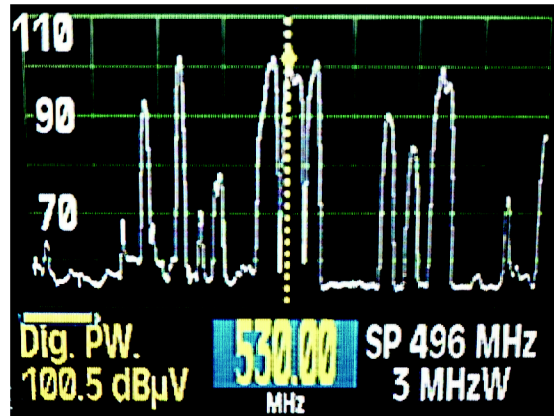


Fig. 2.9: Spectrum analysis for 1-km fiber optic at 530.3 MHz Freq.

· **Automatic C/N:**

This screen-shot gives us information about measurement for C/N for digital channel, which is shown on right-hand of screen in dB. left-hand of screen shows information about power of digital power at 530 MHz. Our results for different lengths of fiber optic at different lengths of fiber optic at different frequencies was same as tables 2.7,2.8,2.9 and 2.10

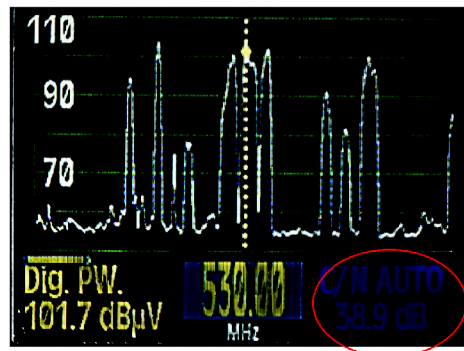


Fig. 2.10: Spectrum analysis for 5-km fiber optic at 530.3 MHz Freq.

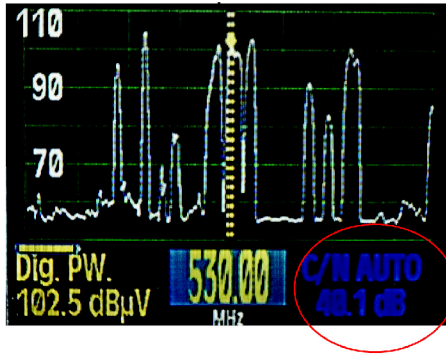


Fig. 2.11: Spectrum analysis for 1-km fiber optic at 530.3 MHz Freq.

· **Carrier Level (Peak Level):**

We can measure carrier level of the tuned channel or tuned frequency. Frequency tuning mode has been selected for our measurement. We prepared carrier level measurement for difference lengths of fiber optic at difference frequencies. In this measurement, Carrier Level of signal or peak level is showed on left-side of spectrum screen. This peak level of received signal decreases by increasing the length of fiber optic. The following Figure 2.12 is a simple of Carrier Level at 530 MHz for 1-Km optical fiber.

Frequency [MHz]	Carrier Level [dBuV]
530	96
506.1	84.6
538	89.8
628.8	89.0
618.65	67.8
674	75.4

Tab. 2.11: Carrier Level measurement for 1-km length of optical fiber

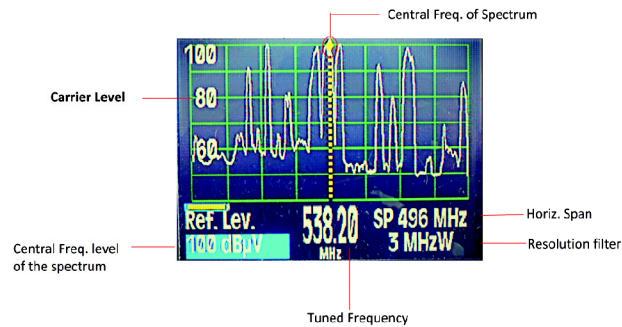


Fig. 2.12: Carrier Level for 1-km fiber optic at 530.3 MHz Freq.

## 2.3 Conclusion

In laboratory days according to our measurements (C/N, Power Signal, Carrier Level, Channel Power), Clearly we found the advantages and disadvantages of fiber optics over coaxial cables.

The following description are advantages of fiber optics over coaxial cables:

- **Powerful in long-distance:** According to our measurement in spectrum-mode of multimeter, we can easily find a powerful received signal on screen for difference lengths of fiber optics.
- **Resistance in electromagnetic interference:** In laboratory measurement in TV-mode and Spectrum-mode, we can prove this theory by Carrier Level and Channel Power measurement.
- **Smaller in size:** Fiber optic compared to coaxial cable use low space in fiber optic transmission. Because Fiber optic has small diameter and they are made of plastic and glass, so have light weight.

Disadvantages of Fiber optic over Coaxial-Cable:

- **Fragility and Brittleness:** Fiber optic has limited physical arc of cables. It can easily break, if we bend it. In addition, Fiber optics made of glass and glass can be affected by various elements



such as Hydrogen. We have to care about them, when deployed under ground.

- **Expensive to buy:** Components of Passive Optical Network (PON) are so expensive compared to traditionally coaxial cable networks.
- **Dispersion and Attenuation:** More long length of cable gives more attenuation of light and light will be disperse.

## 2.4 Measurement equipments

### 1550 nm External Modulation Optical Transmitter Series of HT8500H



Fig. 2.13: Optical Transmitter

Transmitter model of 1550 nm External Modulation (figure2.13), plays the most important role at TV broadcasting. Series of HT8500 1550 nm External Modulation with no laser chirp, large extinction ratio with low dispersion distortion, even can be followed by amplifier when used in long-trunk or local network.

Huatai is the well-known manufacture in analog externally modulated optical transmitter in the world. Excellent performance, high reliability and index, all are reason to select Huatai HT8500 for main distribution links and large or middle link for CATV Network [2].

### Optical Receiver (Lambda Pro 71/72)



Fig. 2.14: Optical Receiver Lambda Pro 71/72

<b>Performance</b>	<b>Index</b>
CTB	$\leq -65$ (dB)
CSO	$\leq -65$ (dB)
SBS	13~18 (dBm)
Network interface port	RJ45, RS232
Power supply	90~265VAC (V)
Power Consume	$\leq 50$ (W)
Work temp.	-5~65 (c)
Storage temp.	-40~85 (c)
Operating relative humidity	5~95 (%)
Size	19×14.5×1.75
Output power	2x7 (dBm)
Return loss	$\geq 50$ (dB)

Tab. 2.12: Technical index of General Feature [Optical Transmitter]

Optical Receiver is an equipment to receive the optical signal and demodulate them to digital electrical signal that can then be processed in any logic circuitry that may be required. The two major important elements in an optical receiver is Photo-Detector and followed by an amplifier for amplification of electrical signal. [19]

Lambda Pro 71/72 Optical Receiver with simple installation and handling designed by VECTOR for usage in different types of Optical network applications. The optical receiver can work and measure the input optical level in range from **-10 dBm** to **+2 dBm**.

**Lambda Pro 71/72 features:**

- 1 active GaAs Output
- Electronic Management
- Digital indication of the Optical receiver level
- Ability to Operate with very low Optical power level
- High Rf signal output level
- Build-in Optical AGC
- Local powering 230VAC

- Monitoring(interface WEB,SNMP,TELNET)

**LAMBDA PRO 71/72 Product Specification:**

<b>Parameters</b>	<b>Index</b>
Wavelength	1100~1600 (nm)
Optical Level input (AGC range)	-7~0 (dBm)
Optical Power Indicator (digital)	-9.9~1.9 (dBm)
Bandwidth	47~862 (MHz)
Flatness	±1
Return Loss	<-20 (dB)
Maximum OutPut level	≥114 (dBμV)
Test point	-20~0.75 (dB)

Tab. 2.13: Technical Index of Optical & RF Feature

<b>Parameters</b>	<b>Index</b>
Powering	230 (VAC)
Power Consumption	<11 (W)
Operation temperature range	-20 ~55 (C)
Optical Connector	SC/APC
RF Connector	F
Monitoring System Connector	RJ45
Monitoring System interface	Ethernet 10/100 Mbps
Protection Class	IP 42
Dimension(WxLXH) <sup>4</sup>	157x136x69 (mm)
Weigth	0.8 Kg

Tab. 2.14: Technical Index of General Feature [Lambda Pro 71/72]

## Antenna Combo 5.1



Fig. 2.15: Antenna Combo 5.1

The Funkce Combo 5.1 as a digital antenna equipped with shielded connectors and cable( makes best protection against Electromagnetic interference) and integrated filters is suitable for indoor and outdoor. The Antenna gives us an opportunity watching TV whenever we want[20]

**The most specific characteristics of Antenna Combo 5.1 are:**

- Applied for indoor and outdoor.
- Channel: UHF 21-69 (470-790 MHz)
- Input Voltage: 5 +/- 0.5 VDC
- Use Female F-Connector

**HD Digital Terrestrial Receiver:**



Fig. 2.16: HD Digital Terrestrial Receiver

At beginning, Digital TV which is connected to DVB-T2 receiver requires a good quality signal, because of that terrestrial indoor or outdoor antenna must be connected to the RF(IN) connector on the back of the receiver.

Generally contains a TV-tuner input and output to a television set also with an external source of signal turning the source signal into content in a form that then be displayed on the television screen or other display device.

<b>Input Frequency</b>	104 ~862MHz
<b>Level Input</b>	-25dBm ~-65dBm(75ohm)
<b>Input Voltage</b>	AC90-250V, 50/60Hz
<b>Material</b>	Metal/Plastic
<b>Demodulation</b>	QAM 256 QAM 64 QAM 32 QAM16 QPSK
<b>USB</b>	Support
<b>Transponder</b>	DVB-T2 /T

Tab. 2.15: Technical Index of General Feature [DVB-T2 Receiver]

## Televés Multimeter FSM 450



Fig. 2.17: Televés Multimeter FSM 450

The FSM 450 with 5" color TV signal has all functions, which are necessary to guarantee the quality of an analogue and digital TV installation. It is powerful and easy to handle, designed to measure both analog (Level, C / N, V / A) and digital (power In the terrestrial band (47-860 MHz) and in the satellite band (950-2150 MHz). In the analyzer mode, the GSM band (860-950 MHz) and (5-47 MHz) which makes spectrum analyzer works on all frequencies between 5 and 2150 MHz.

<b>Screen</b>	5 inch
<b>Synchronization</b>	5 Hz
<b>Weight</b>	5,5 kg
<b>Dimensions</b>	280 x 130 x 310
<b>Battery</b>	Ni-MH 12V, 6Ah
<b>External power supply</b>	DC adapter (12-14,8 V)
<b>Measurement unit</b>	dBuV
<b>Frequency range</b>	Terrestrial (47-860 MHz )
<b>Frequency resolution</b>	50 kHz Ter
<b>Level resolution</b>	0,1 dB
<b>Analogue measurements</b>	level, C / N, V / A, synchro-pulse display
<b>Digital measurement</b>	DCP, C/N, BER, MPEG
<b>Bandwidth</b>	250 kHz Ter
<b>SPAN</b>	Ter.: optional (8, 16, 32, 48, 96, 192, 496 MHz)
<b>Height</b>	up to 2000 m

Tab. 2.16: Technical Index Of General Feature [FSM 450]

### 3 CONCLUSION

Nowadays Digital Video Broadcasting needs delivery more television channels with the best quality. Because of increasing the harmonic and inter-modulation distortion, One of the best way to solve this problem is transmission TV signals over Fiber Optic. Fiber Optic can significantly reduce the distortion by Modulation Linearity of laser or other modulation method.

According to the practical part and our topology in Figure 2.3, The performance of Optical Receiver depends on amplifier design and Photodetectors. Conversion of optical signals back into electronic signals, amplification and extracting the data are main roles of Optical Receiver. One of the most significant parameter in optical receiver is receiver sensitivity. Receiver sensitivity is as a minimum average optical power for a defined Bit-Error rate (BER). LAMBDA PRO 71 Optical Receiver, which is used in practical fiber has ability to operate at low optical power levels and with a high RF output level is best choice to examine the received TV signals.

Optical Transmitter acts as a converter of electrical signal to optical signal, and transmit a modulated optical signal into optical fiber. The most significant distortions, which disturbance the performance of optical transmitter are: Laser Chirp, Dispersion Distortion, Extinction Ratio, CSO Distortion. We can limit these disturbances by using an external modulator. The used optical transmitter with ability to externally modulation n practical part is HT8500H Series 1550 nm External Modulation Optical Transmitter.

Generally, the most significant advantages of Fiber Optic, which we noticed in the practical part of Bachelor Thesis are:

- **High Bandwidth:**The volume of data over Fiber Optics is greater than Copper base cables.
- **Longer Distance:**Fiber Optic with losing low power, cause transmission over longer distance.



- **More secure against Electromagnetic Interference:**Fiber Optic with very low rate of bit error ( $10 e^{-13}$ ) is more resistance to electromagnetic interference.
- **Small Size:**Fiber Optic with small diameter, cause saving more space in transmission.
- **High-Quality:** Transmitted Signal, which received with Optical Receiver, is Amplified by Optical Receiver.

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## LIST OF SYMBOLS, PHYSICAL CONSTANTS AND ABBREVIATIONS

CATV	Community Antenna Television
LAN	Local Area Network
WAN	Wide Area Network
PSTN	Public Switch Telephone Network
RF	Radio Frequency
AM-VSB	Amplitude Modulation-Vestigial Sideband
DM	Directly Modulator
EM	Externally Modulator
DFB	Distributed Feedback Laser
QAM	Quadrature Amplitude Modulated
QPSK	Quadrature Phase Shift Keying
MPEG	Moving Picture Experts Group
UHF	Ultra High Frequency
BER	Bit Error Rate
VHF	Very High Frequency
CSO	Composite Second Error
AGC	Automate Gain Control
SNR	Signal-To-Noise-Ratio
PLL	Phase Locked Loop
DVB-S	Digital Video Broadcasting by Satellite
DVB-C	Digital Video Broadcasting by Cable
DVB-T	Digital Video Broadcasting by Terrestrial
BW	BandWidth
SVCD	Service Code Dialing
ISDB	Integrated Services Digital Broadcasting
HFC	Hybrid Fiber Coaxial
FTTH	Fiber To The Home
SONET	Synchronous Optical Network

PH	Primary Hub
CO	Central Office
PON	Passive Optical Network
POTS	Plain Old Telephone Service
OFDM	orthogonal Frequency Division Multiplex
RZ	Return to Zero
NRZ	Not Return to Zero
MZI	Mach-Zhender interferometer
LED	Light-Emitting Diode
WDM	Wave Division Multiplexing