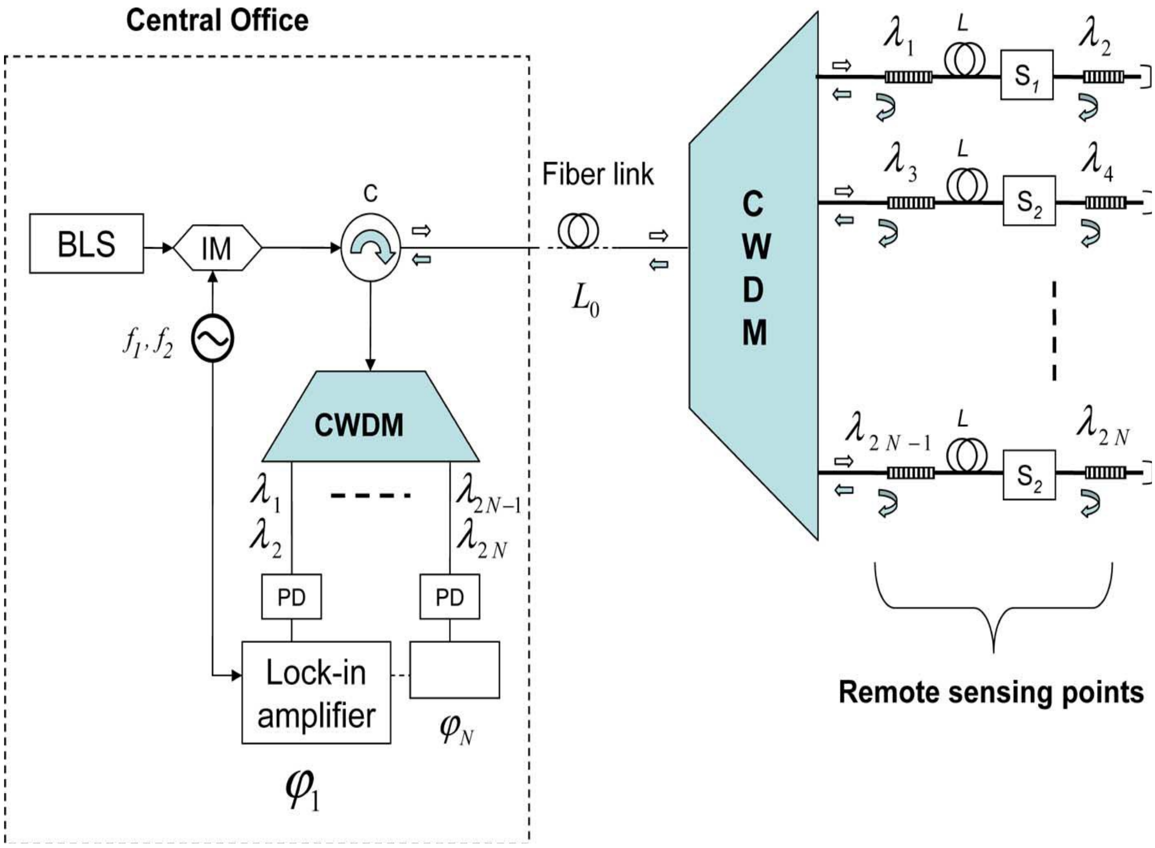
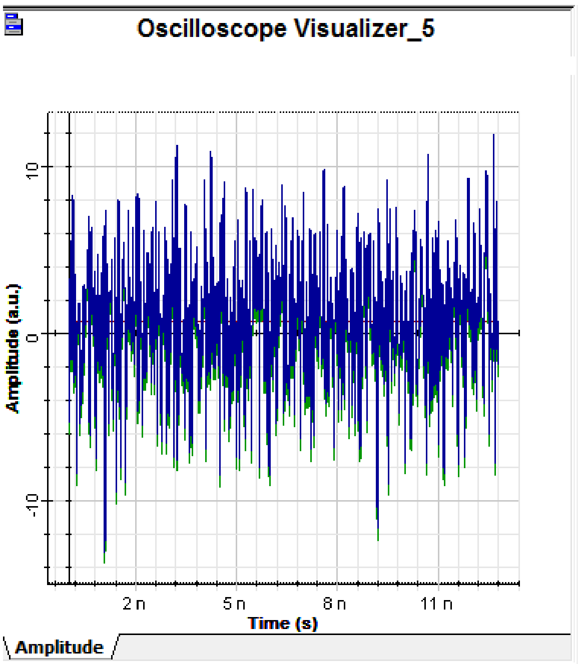
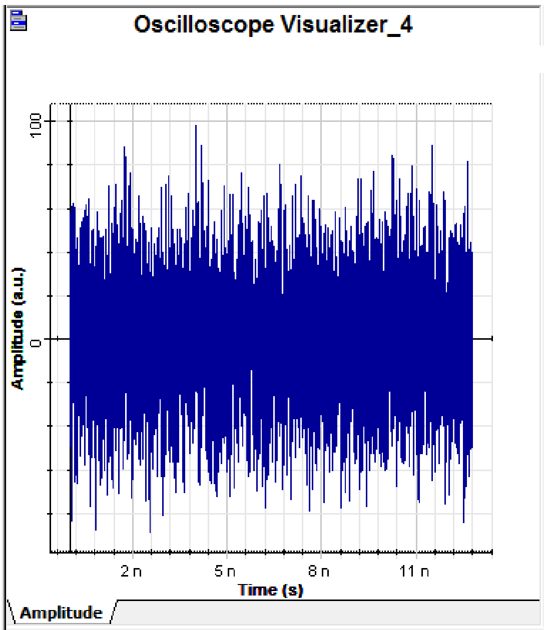
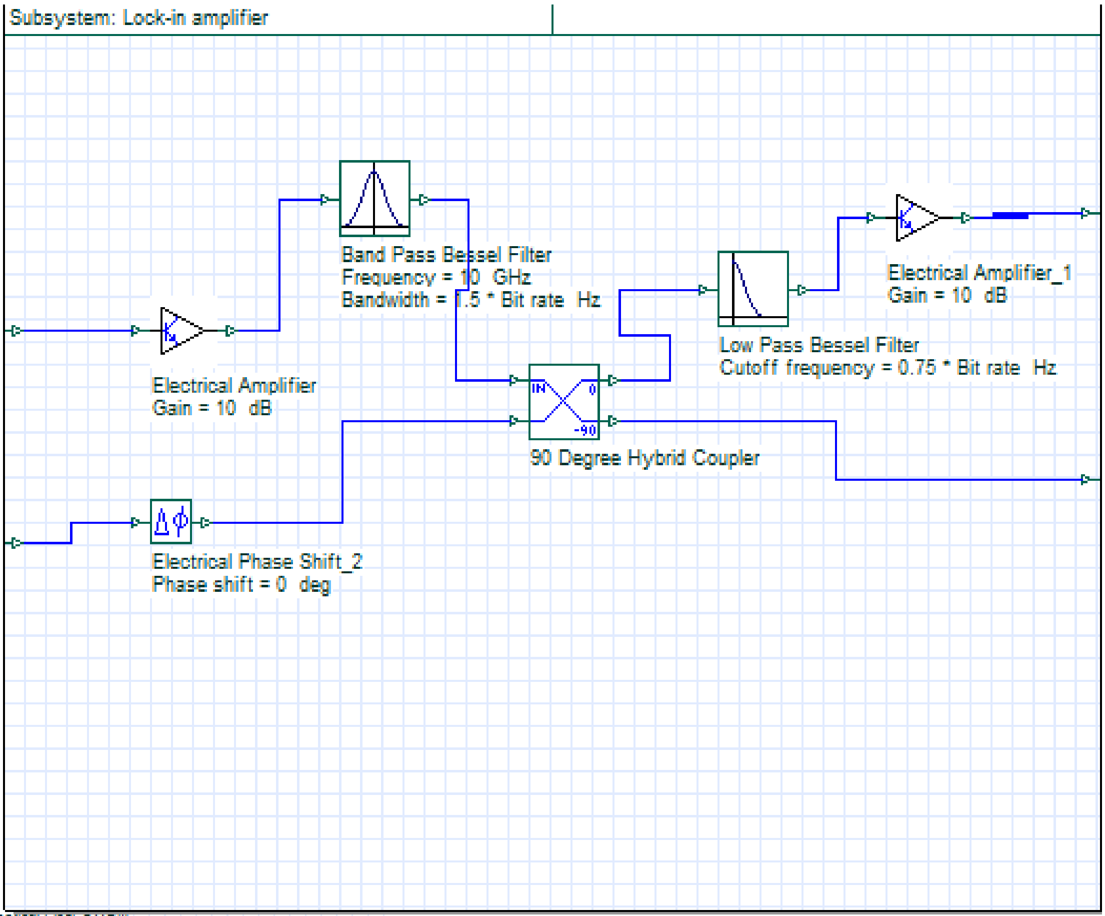
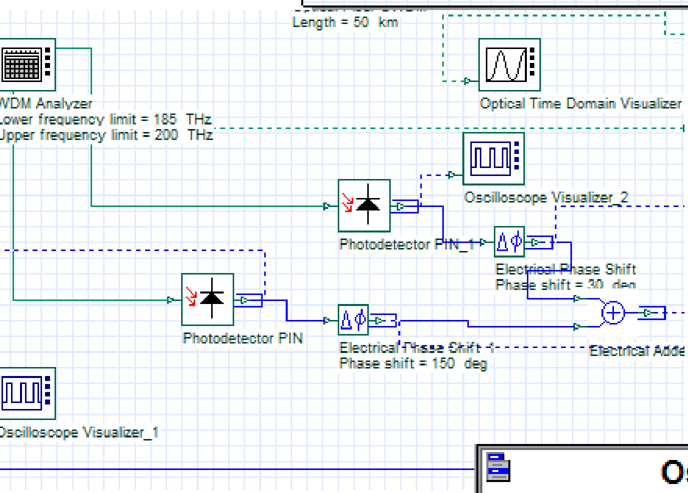
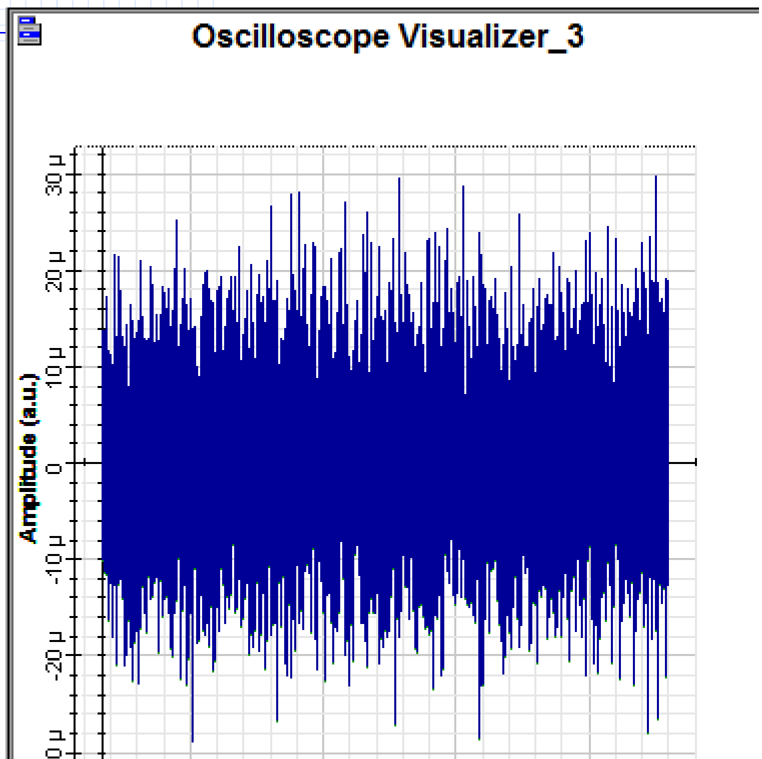

Central Office
BLS
IM
C
f_1, f_2
CWDM
λ_1
λ_2
λ_{2N-1}
λ_{2N}
PD
PD
Lock-in amplifier
φ_1
φ_N
Fiber link
L_0
CWDM
λ_1
λ_2
λ_3
λ_4
λ_{2N-1}
λ_{2N}
L
S_1
S_2
S_2
Remote sensing points

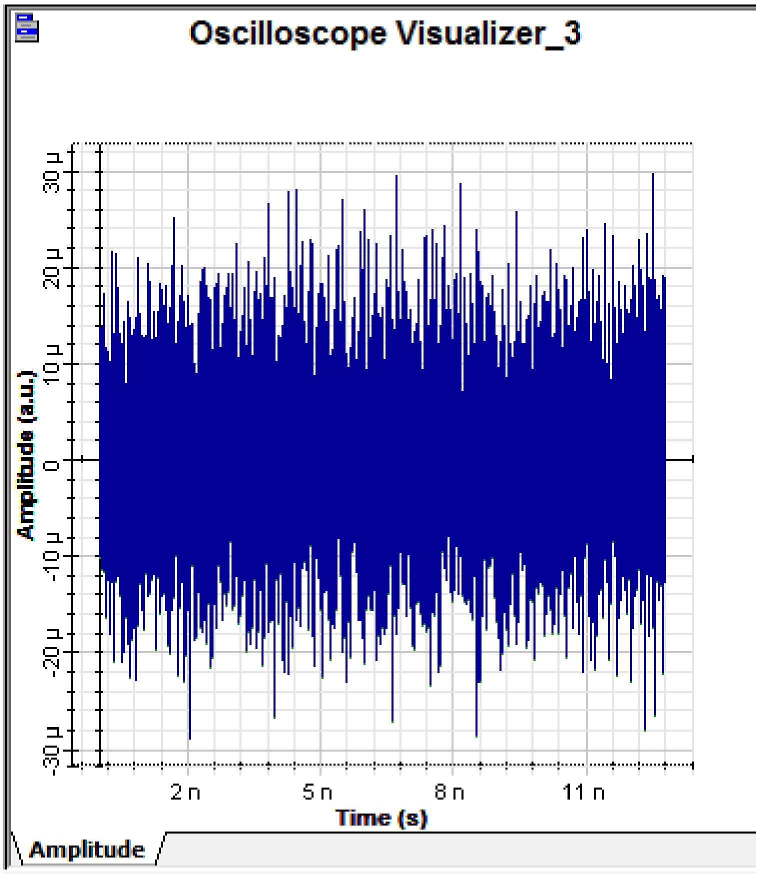

Oscilloscope Visualizer_5
Amplitude (a.u.)
10
0
-10
2 n
5 n
8 n
11 n
Time (s)
Amplitude

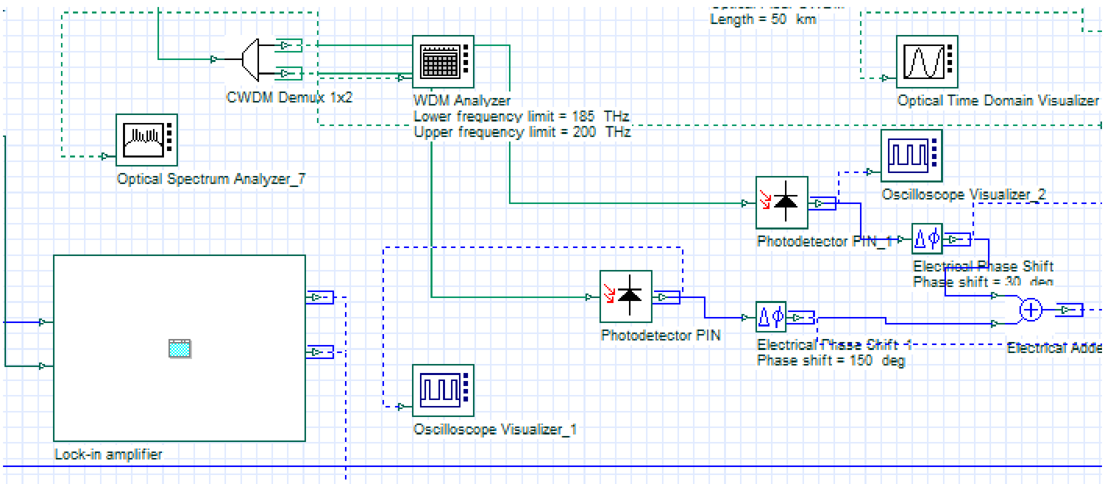

Oscilloscope Visualizer_4
Amplitude (a.u.)
100
0
2 n
5 n
8 n
11 n
Time (s)
Amplitude

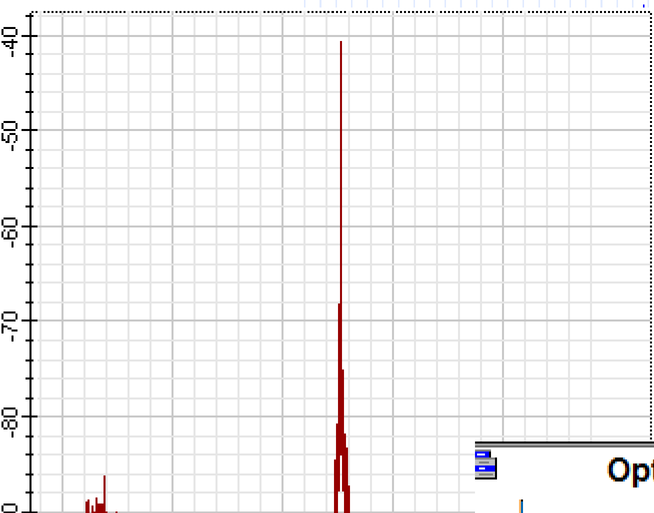

Subsystem: Lock-in amplifier
Band Pass Bessel Filter
Frequency = 10 GHz
Bandwidth = 1.5 * Bit rate Hz
Electrical Amplifier_1
Gain = 10 dB
Low Pass Bessel Filter
Cutoff frequency = 0.75 * Bit rate Hz
Electrical Amplifier
Gain = 10 dB
IN
0
-90
90 Degree Hybrid Coupler
Electrical Phase Shift_2
Phase shift = 0 deg

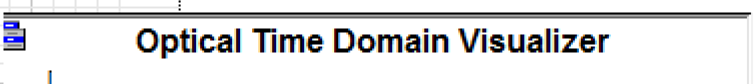

Length = 50 km
Optical Time Domain Visualizer
WDM Analyzer
Lower frequency limit = 185 THz
Upper frequency limit = 200 THz
Oscilloscope Visualizer_2
Photodetector PIN_1
Photodetector PIN
Electrical Phase Shift_1
Phase shift = 150 deg
Oscilloscope Visualizer_1

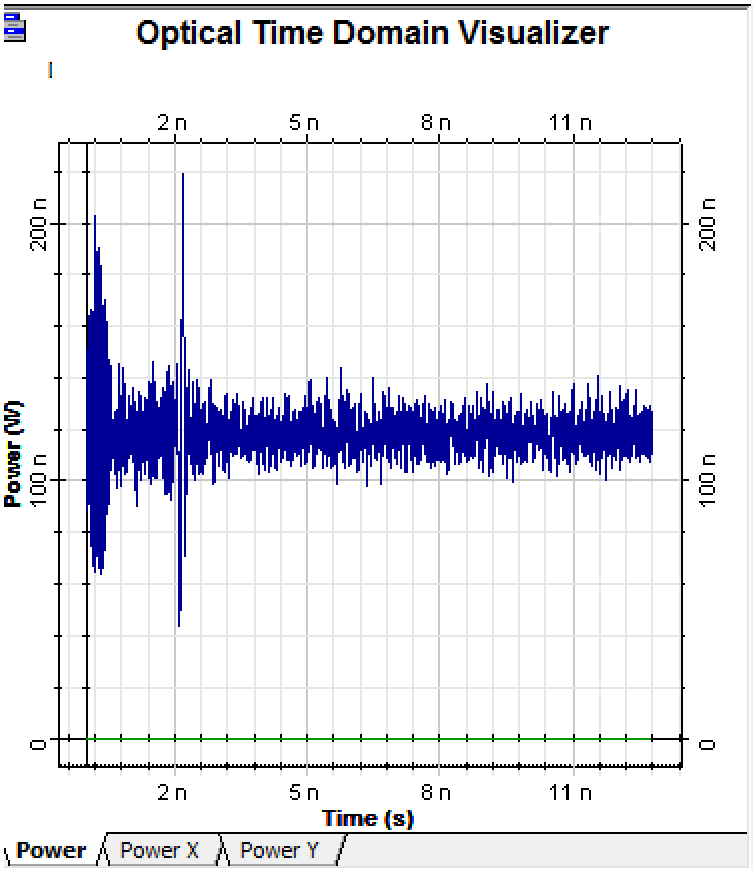

Oscilloscope Visualizer_3
Amplitude (a.u.)
30 µ
20 µ
10 µ
0
-10 µ
-20 µ

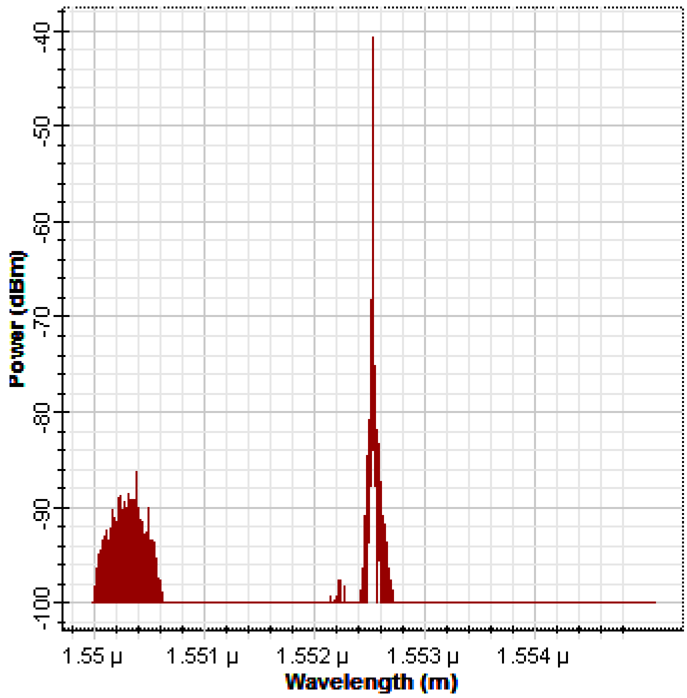

Oscilloscope Visualizer_3
Amplitude (a.u.)
30 µ
20 µ
10 µ
0
-10 µ
-20 µ
-30 µ
2 n
5 n
8 n
11 n
Time (s)
Amplitude

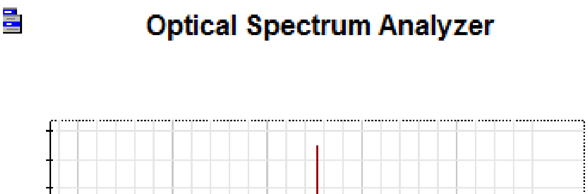

Length = 50 km
CWDM Demux 1x2
WDM Analyzer
Lower frequency limit = 185 THz
Upper frequency limit = 200 THz
Optical Time Domain Visualizer
Optical Spectrum Analyzer_7
Oscilloscope Visualizer_2
Photodetector PIN_1
Electrical Phase Shift
Phase shift = 30 deg
Photodetector PIN
Electrical Phase Shift_1
Phase shift = 150 deg
Electrical Adde
Oscilloscope Visualizer_1
Lock-in amplifier

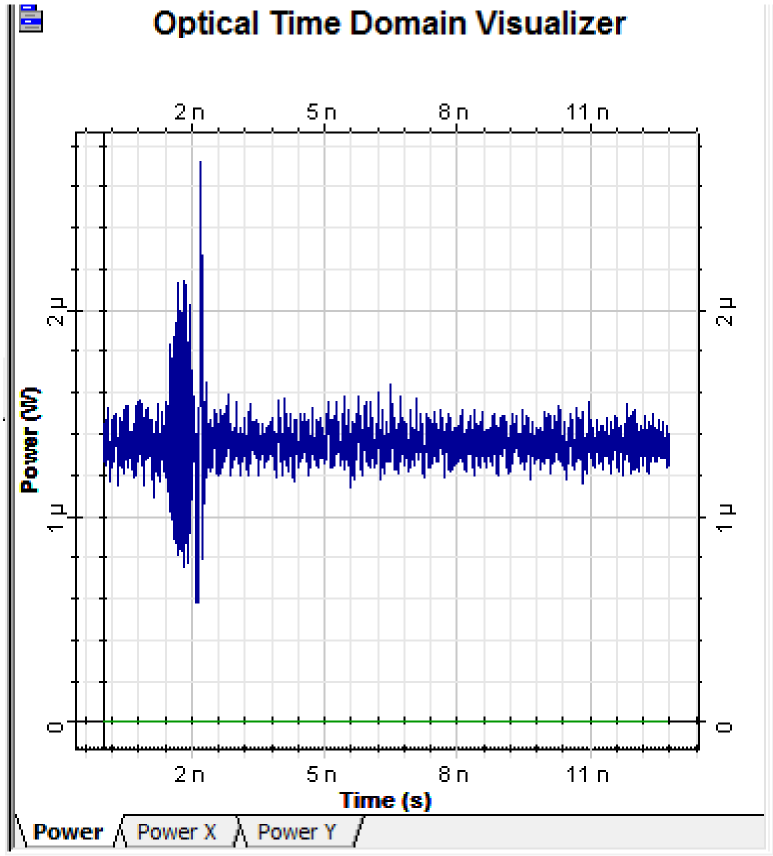

-40
-50
-60
-70
-80

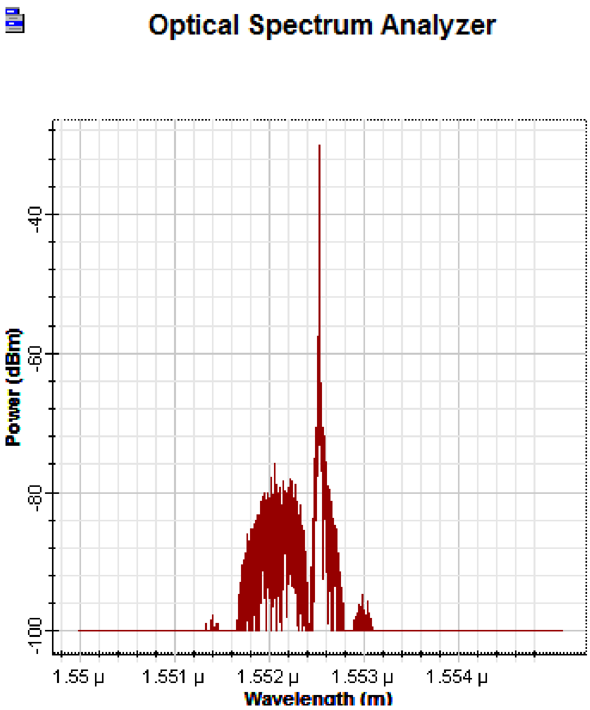

Optical Time Domain Visualizer

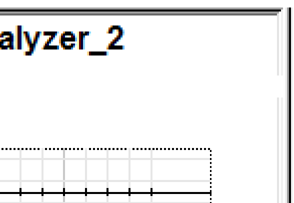

Optical Time Domain Visualizer
2 n
5 n
8 n
11 n
200 n
100 n
0
Power (W)
Time (s)
Power
Power X
Power Y


-40
-50
-60
-70
-80
-90
-100
Power (dBm)
1.55 μ
1.551 μ
1.552 μ
1.553 μ
1.554 μ
Wavelength (m)

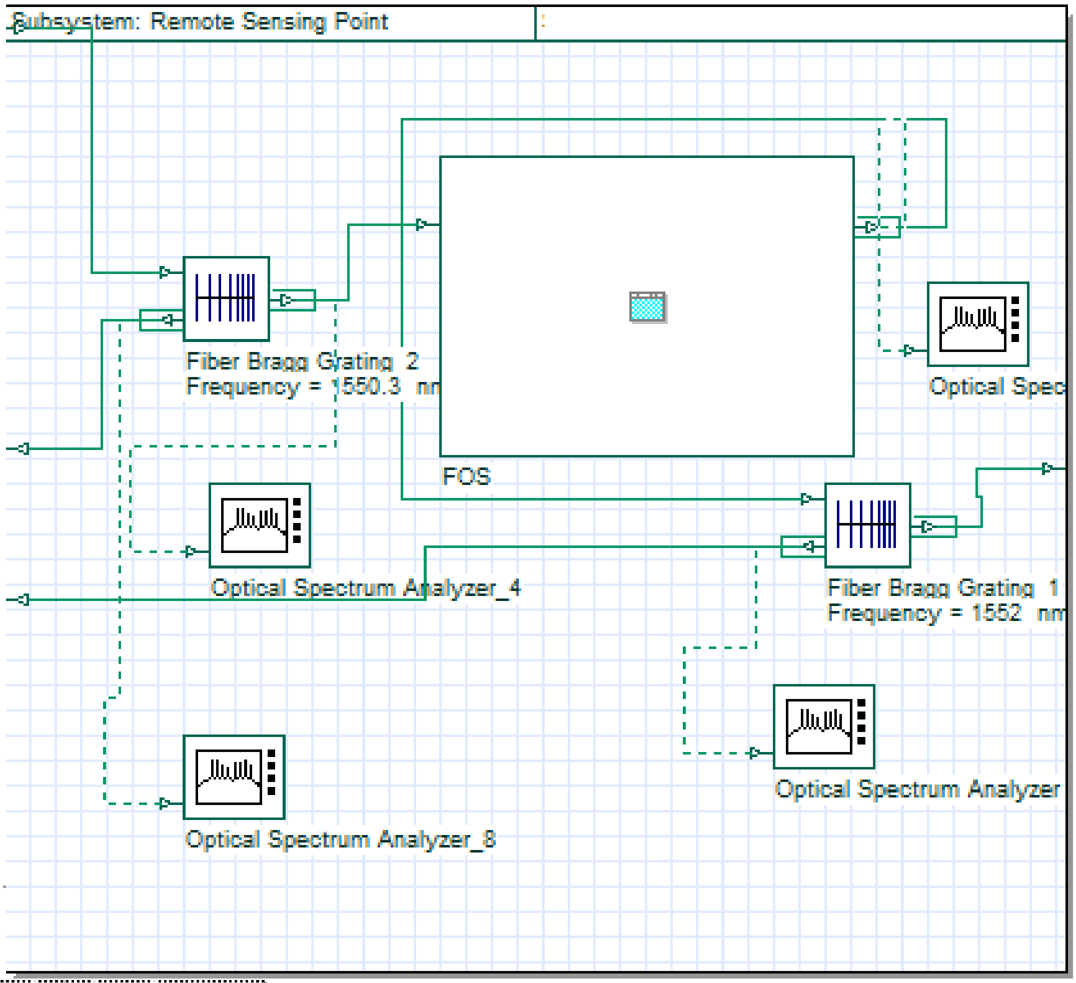

Optical Spectrum Analyzer


Optical Time Domain Visualizer
2 n
5 n
8 n
11 n
2 μ
1 μ
0
Power (W)
Time (s)
Power
Power X
Power Y

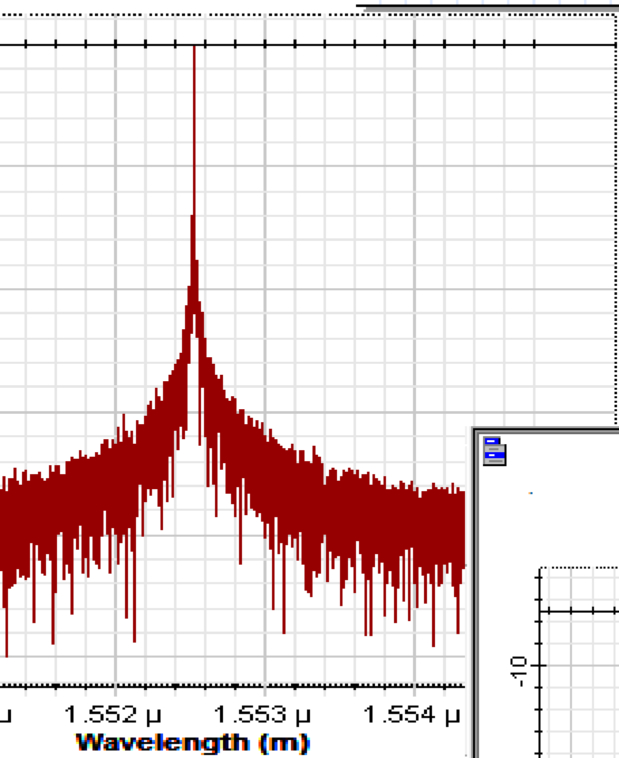

Optical Spectrum Analyzer
-40
-60
-80
-100
Power (dBm)
1.55 μ
1.551 μ
1.552 μ
1.553 μ
1.554 μ
Wavelength (m)


alyzer_2

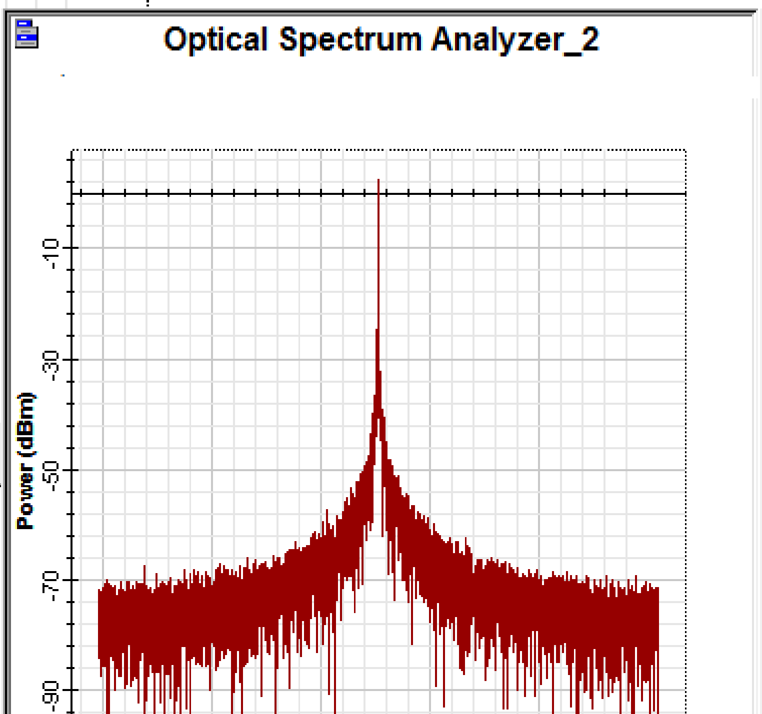
λ λ



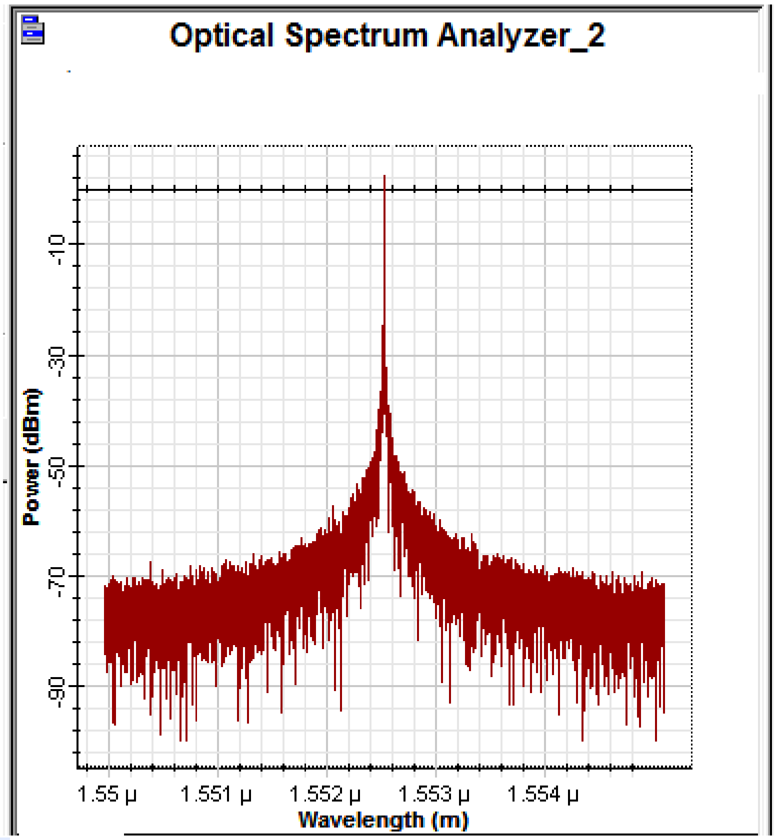
Subsystem: Remote Sensing Point
Fiber Bragg Grating 2
Frequency = 1550.3
Optical Spec
FOS
Optical Spectrum Analyzer_4
Fiber Bragg Grating 1
Frequency = 1552
Optical Spectrum Analyzer
Optical Spectrum Analyzer_8

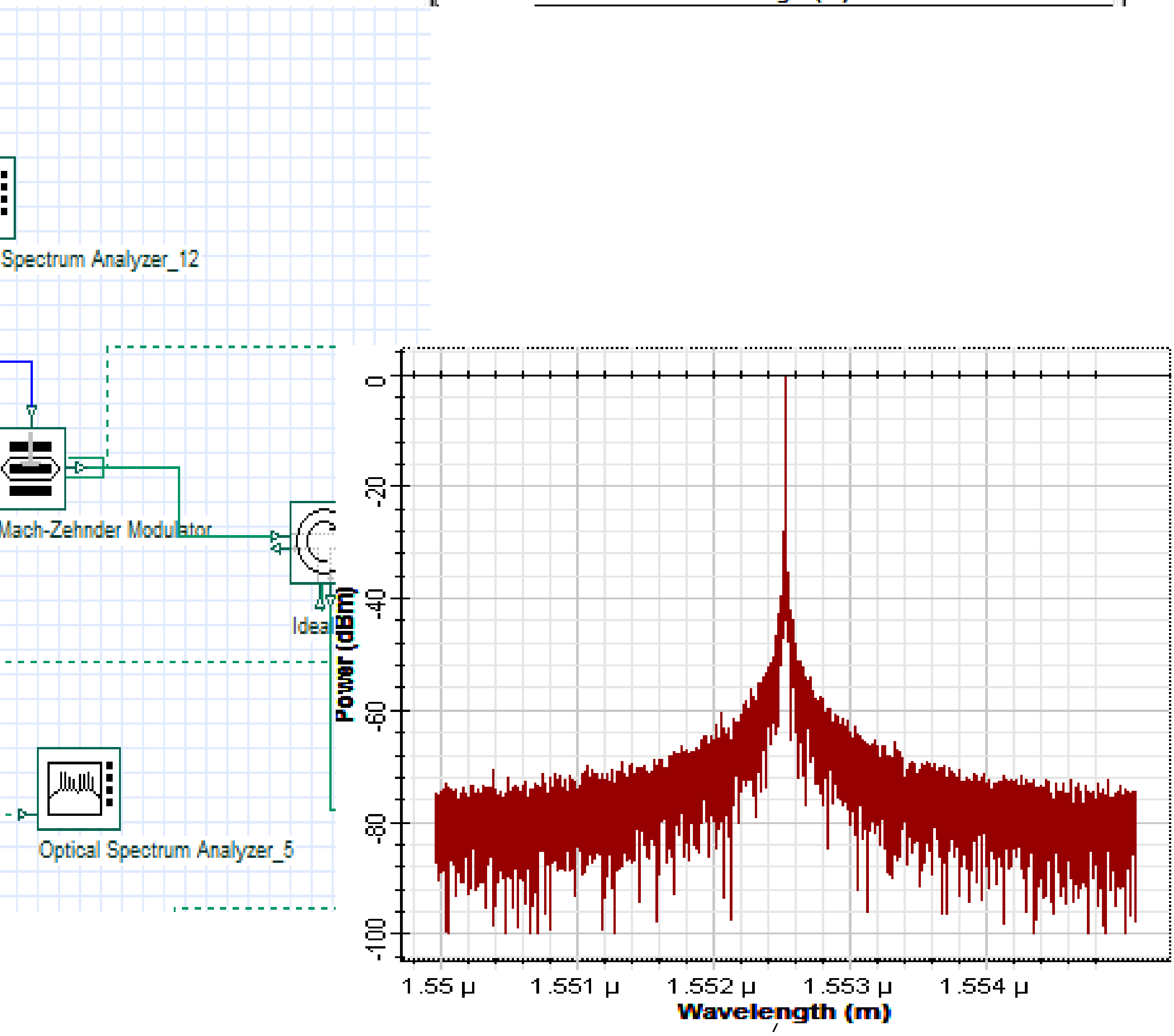


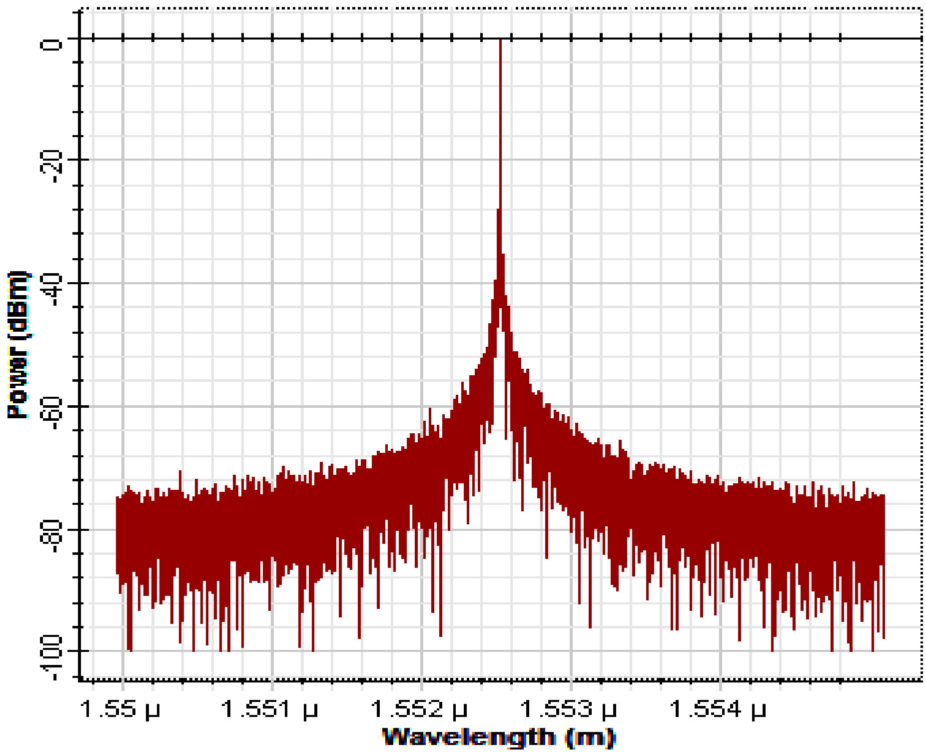
1.552 μ
1.553 μ
1.554 μ
Wavelength (m)

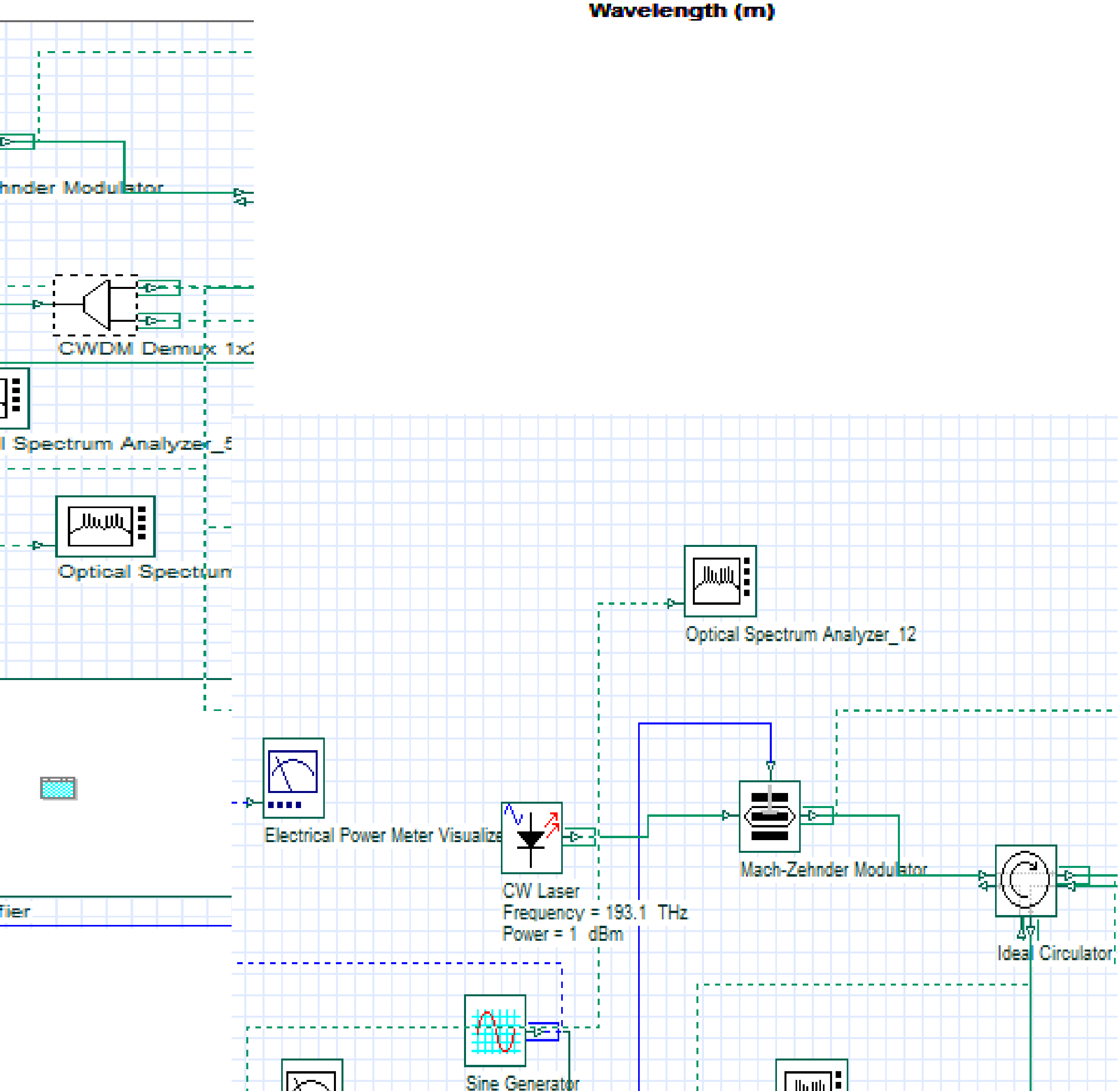


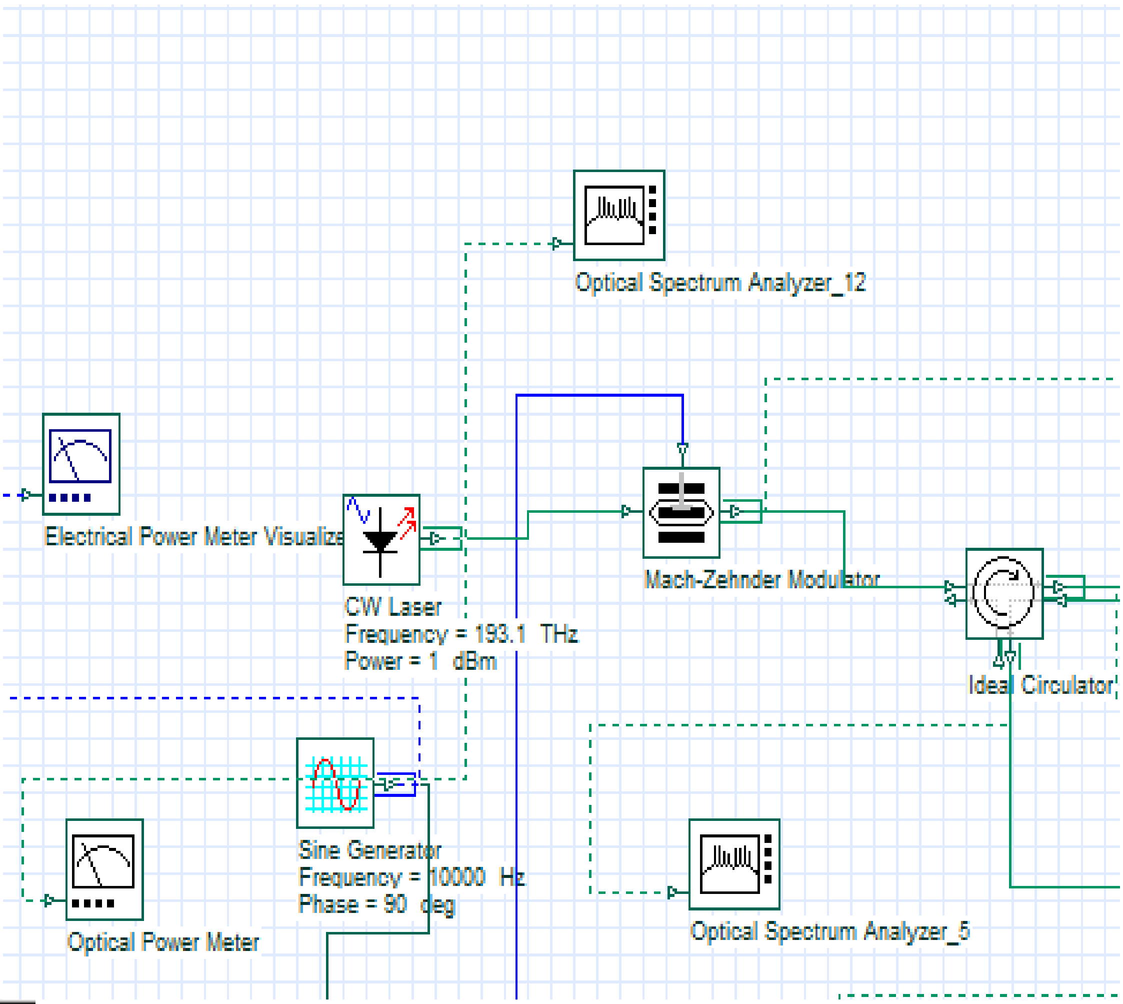
Optical Spectrum Analyzer_2
Power (dBm)
-10
-30
-50
-70
-90

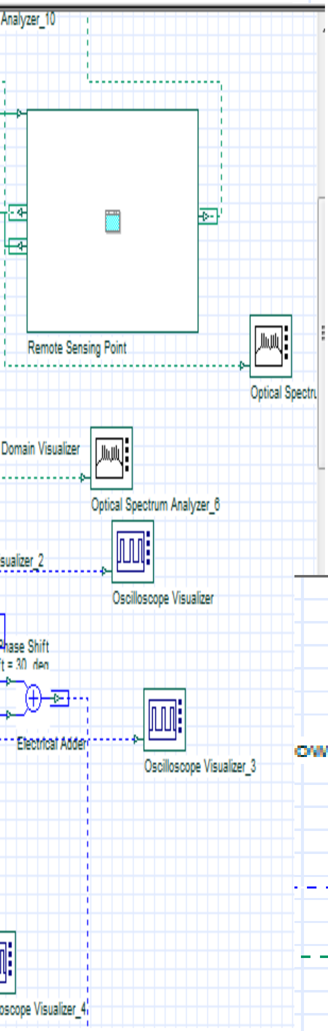

Optical Spectrum Analyzer_2
Power (dBm)
-10
-30
-50
-70
-90
1.55 µ
1.551 µ
1.552 µ
1.553 µ
1.554 µ
Wavelength (m)


Spectrum Analyzer_12
Mach-Zehnder Modulator
Ideal
Optical Spectrum Analyzer_5
Power (dBm)
0
-20
-40
-60
-80
-100
1.55 µ
1.551 µ
1.552 µ
1.553 µ
1.554 µ
Wavelength (m)


Power (dBm)
0
-20
-40
-60
-80
-100
1.55 µ
1.551 µ
1.552 µ
1.553 µ
1.554 µ
Wavelength (m)

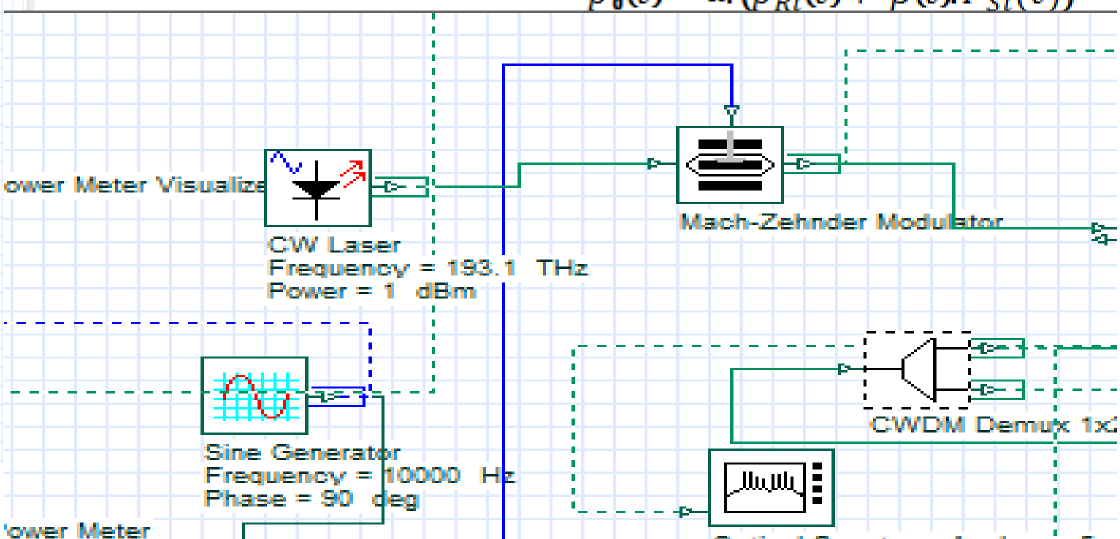

CWDM Demux 1x2
Electrical Power Meter Visualize
CW Laser
Frequency = 193.1 THz
Power = 1 dBm
Optical Spectrum Analyzer_12
Mach-Zehnder Modulator
Ideal Circulator
Sine Generator

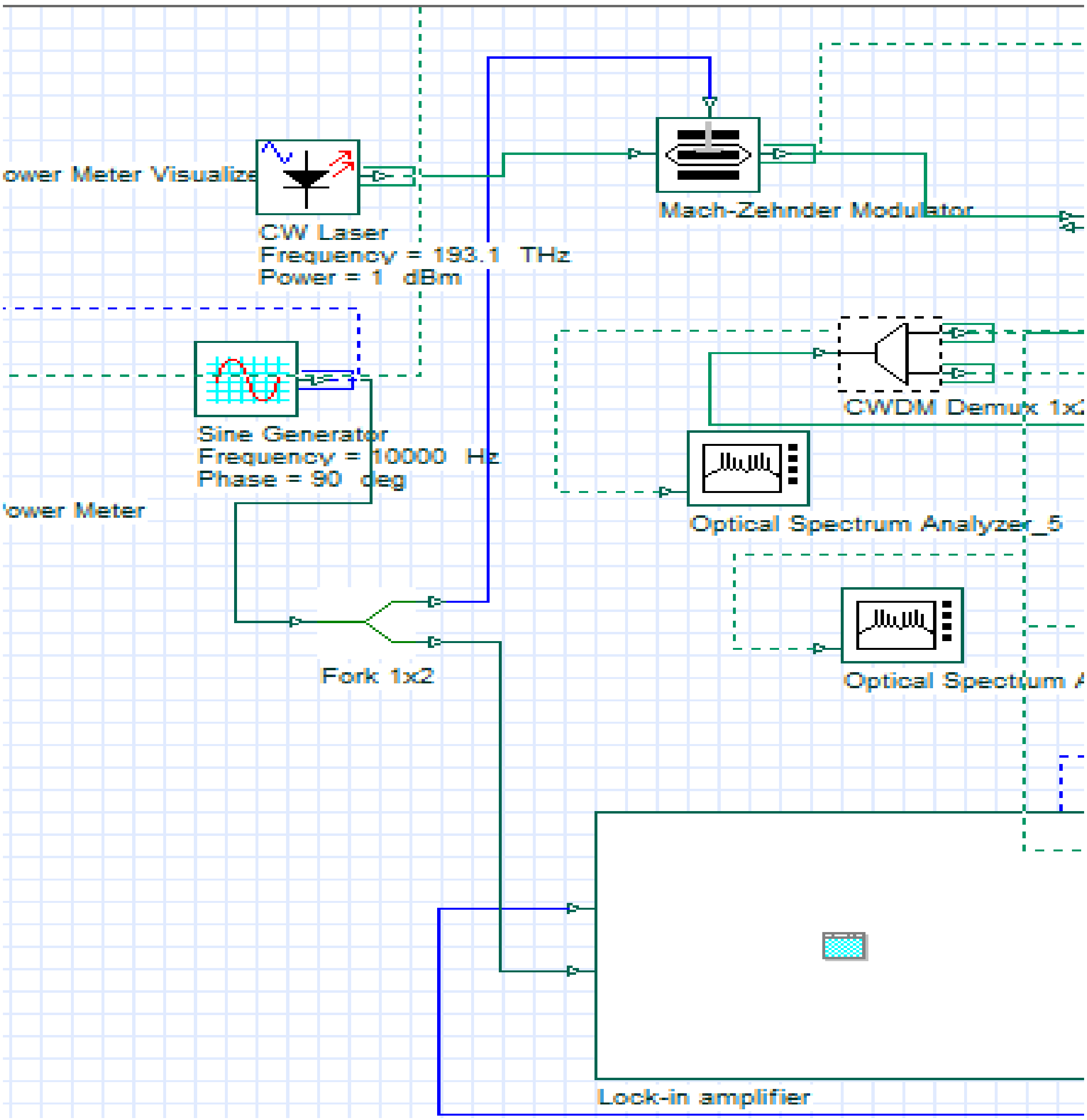




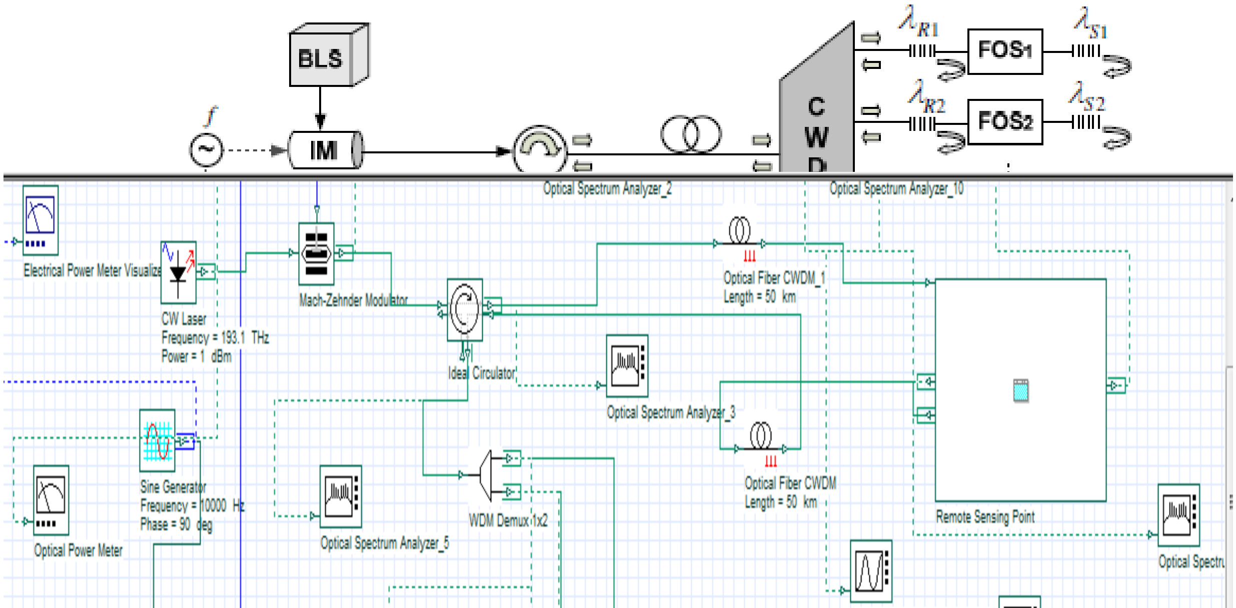
$$\alpha = (m_{Ri}.R(\lambda_{Ri}).d_{Ri}) \quad \beta 1 = \frac{m_{si}.R(\lambda_{si}).d_{si}}{m_{Ri}.R(\lambda_{Ri}).d_{Ri}} H_1^2$$

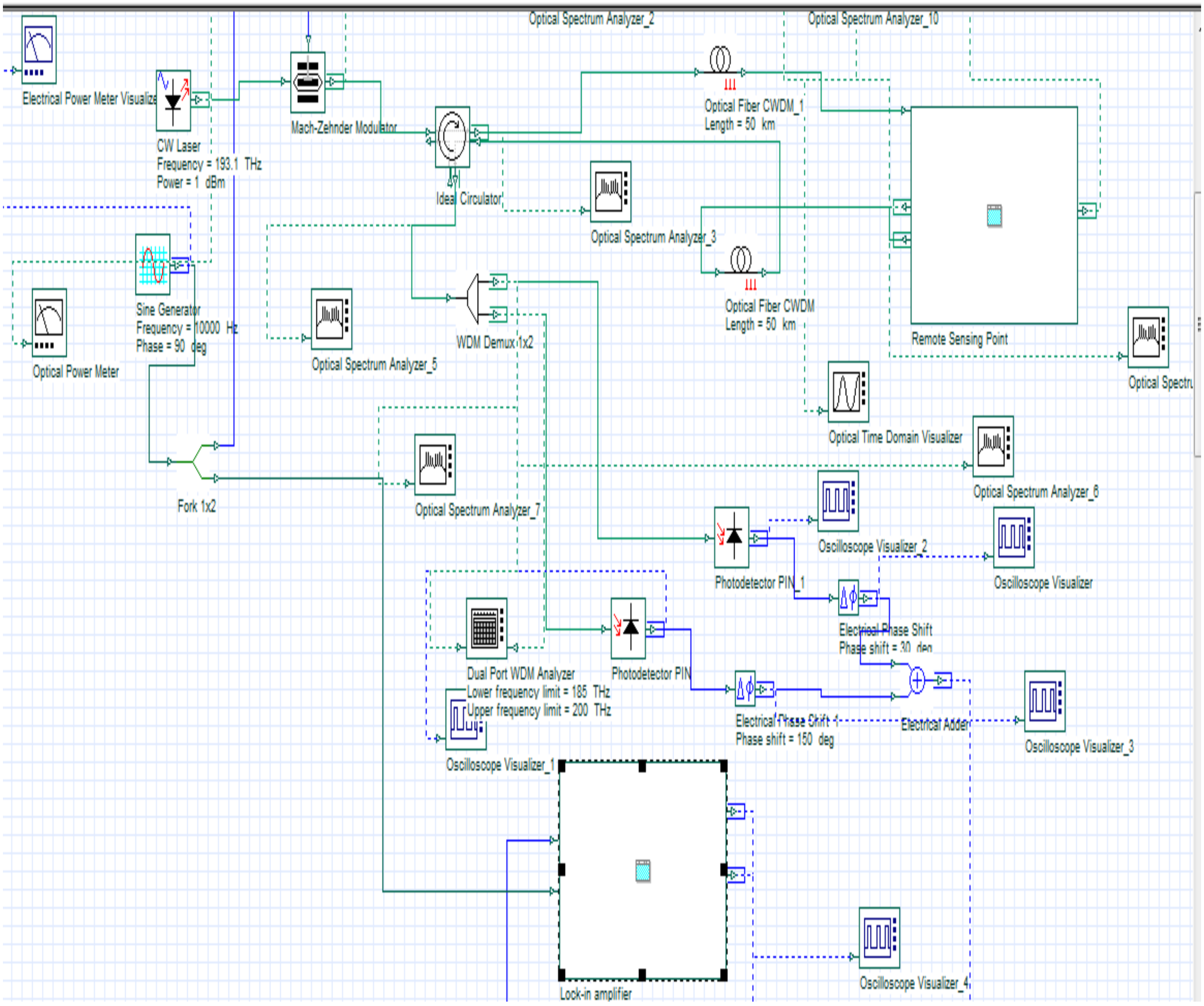
$$p_0(t) = \alpha.(p_{Ri}(t) + \beta(t).P_{si}(t))$$





$$\frac{\ldots_{si}.R(\lambda_{si}).d_{si}}{\ldots_{Ri}.R(\lambda_{Ri}).d_{Ri}} H_1^2$$

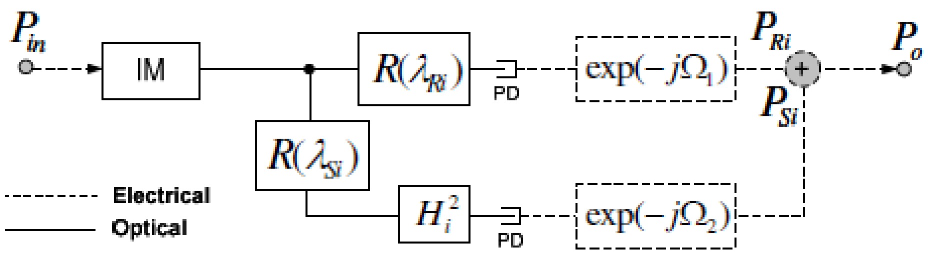




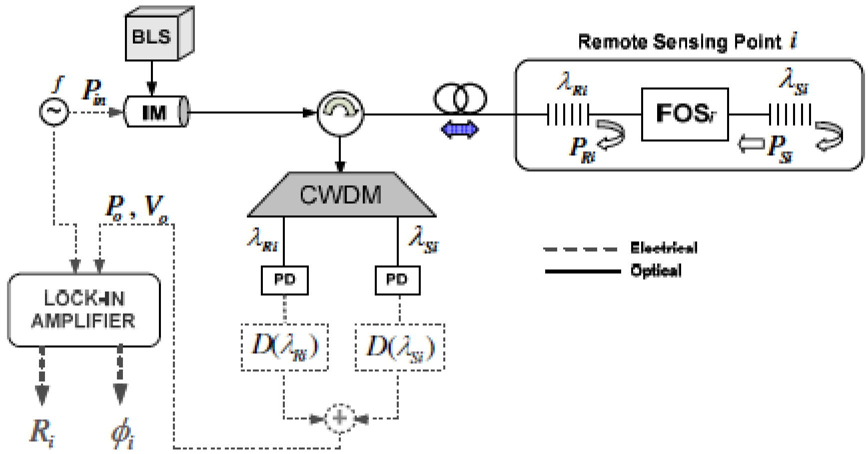
$$\propto . = (m_{Ri}.R(\lambda_{Ri}).d_{Ri}) \quad \beta 1 = \frac{m_{si}.R(\lambda_{si}).d_{si}}{m_{Ri}.R(\lambda_{Ri}).d_{Ri}} H_1^2$$

$$p_0(t) = \propto .(p_{Ri}(t) + \beta(t).P_{si}(t))$$

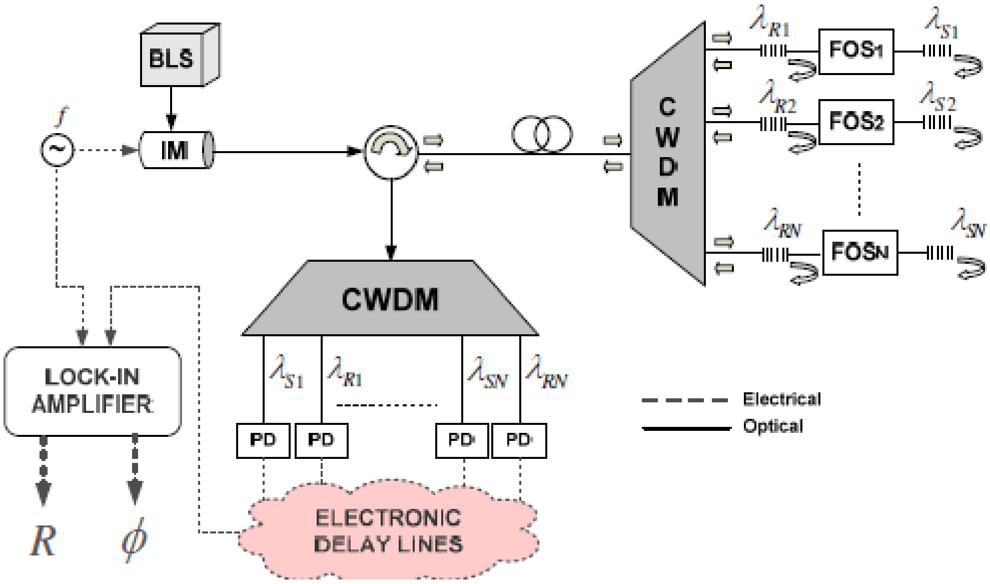
Ω Ω



P_{in}
IM
$R(\lambda_{Ri})$
PD
$\exp(-j\Omega_1)$
P_{Ri}
P_o
$R(\lambda_{Si})$
P_{Si}
H_i^2
PD
$\exp(-j\Omega_2)$
Electrical
Optical

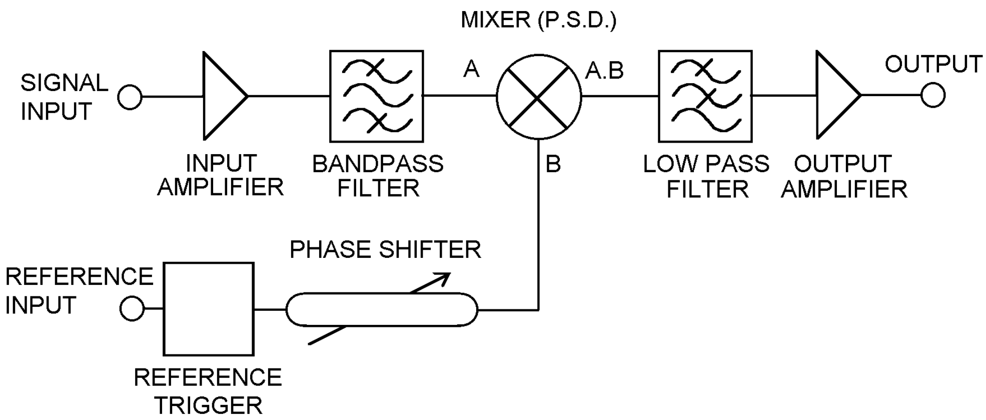


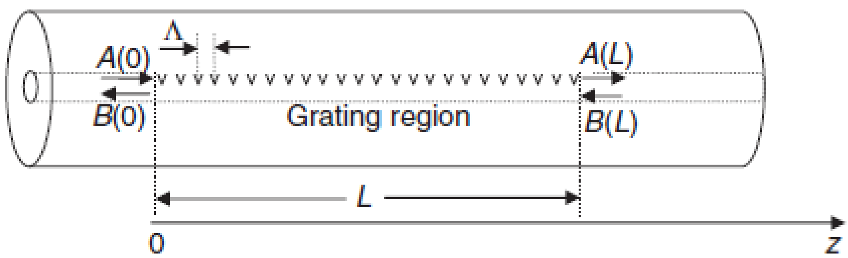
BLS
f
P_{in}
IM
Remote Sensing Point i
λ_{Ri}
FOS$_i$
λ_{Si}
P_{Ri}
P_{Si}
CWDM
P_o, V_o
λ_{Ri}
λ_{Si}
PD
PD
$D(\lambda_{Ri})$
$D(\lambda_{Si})$
LOCK-IN AMPLIFIER
R_i
ϕ_i
Electrical
Optical



BLS
f
IM
C W D M
λ_{R1}
FOS1
λ_{S1}
λ_{R2}
FOS2
λ_{S2}
λ_{RN}
FOSN
λ_{SN}
CWDM
LOCK-IN AMPLIFIER
λ_{S1}
λ_{R1}
λ_{SN}
λ_{RN}
PD
PD
PD
PD
ELECTRONIC DELAY LINES
R
ϕ
Electrical
Optical

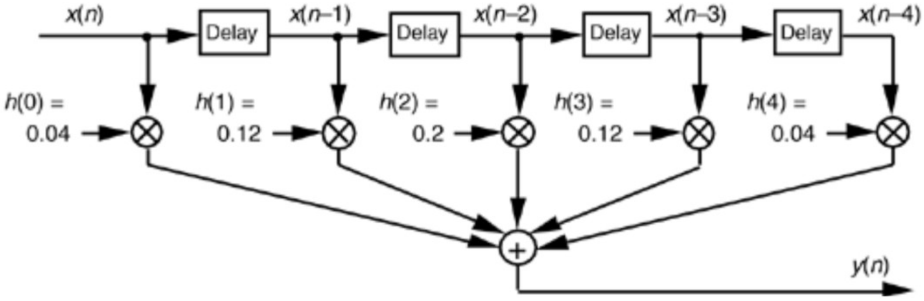
FIR filter

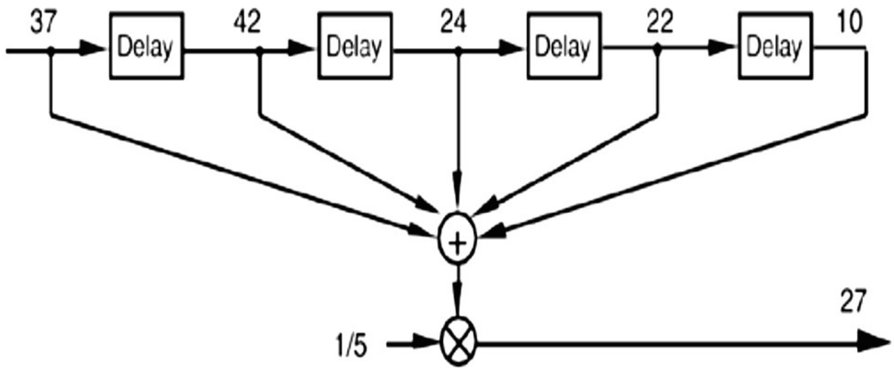


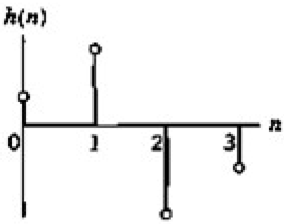


$n_{core}\, n_{core}$

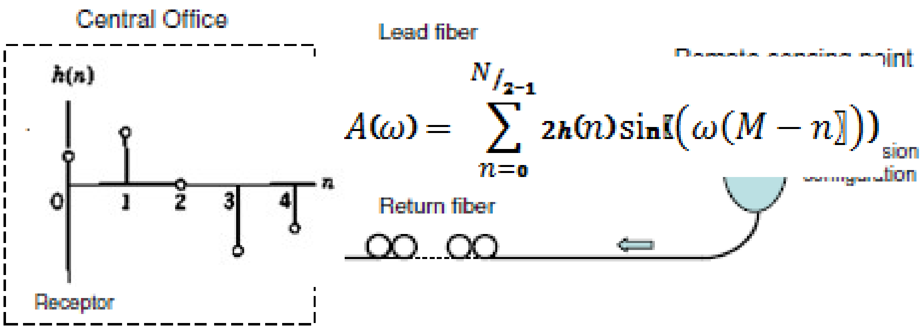
$$n(z) = \mathbf{n_{core}} + \delta n \left\{ \mathbf{1} + \cos\left(\frac{\mathbf{2}\pi}{A} z \right) \right\}$$



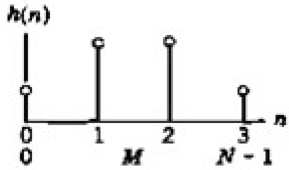




$$H(\omega) = \sum_{n=0}^{N-1} h(n) e^{-j\omega n}, \quad H(\omega) = e^{-j\omega M} \sum_{n=0}^{N-1} h(n) e^{-j\omega(M-n)},$$

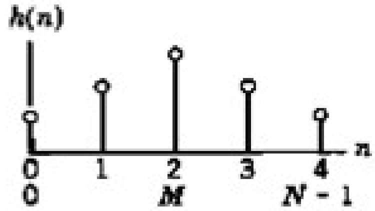


$$A(\omega) = \sum_{n=0}^{N/2-1} 2h(n) \sin(\omega(M-n))$$

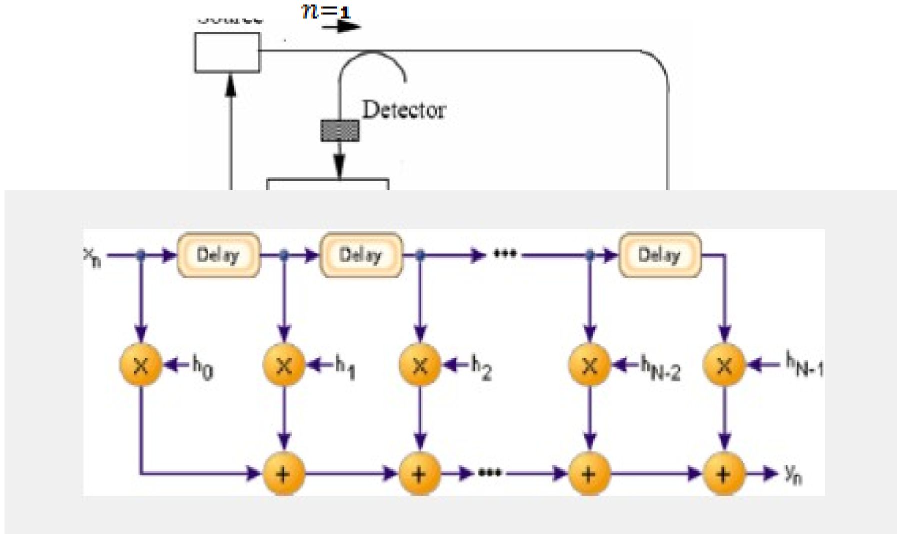


$$A(\omega) = \sum_{n=0}^{M-1} 2h(n)\sin(\omega(M-n))$$

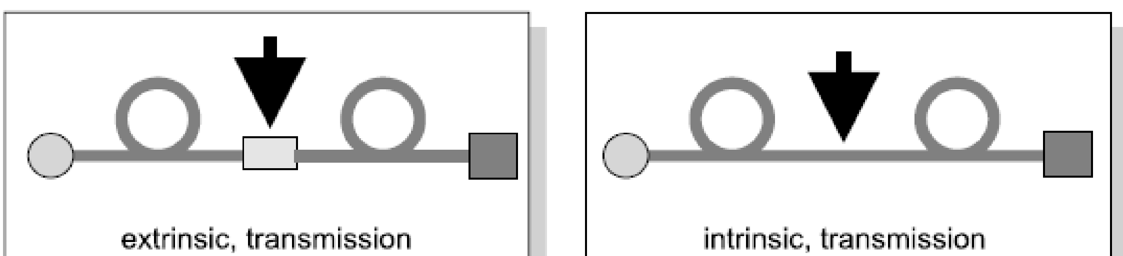
$$A(\omega) = \sum_{n=0}^{N/2-1} 2h(n)\cos(\omega(M-n))$$

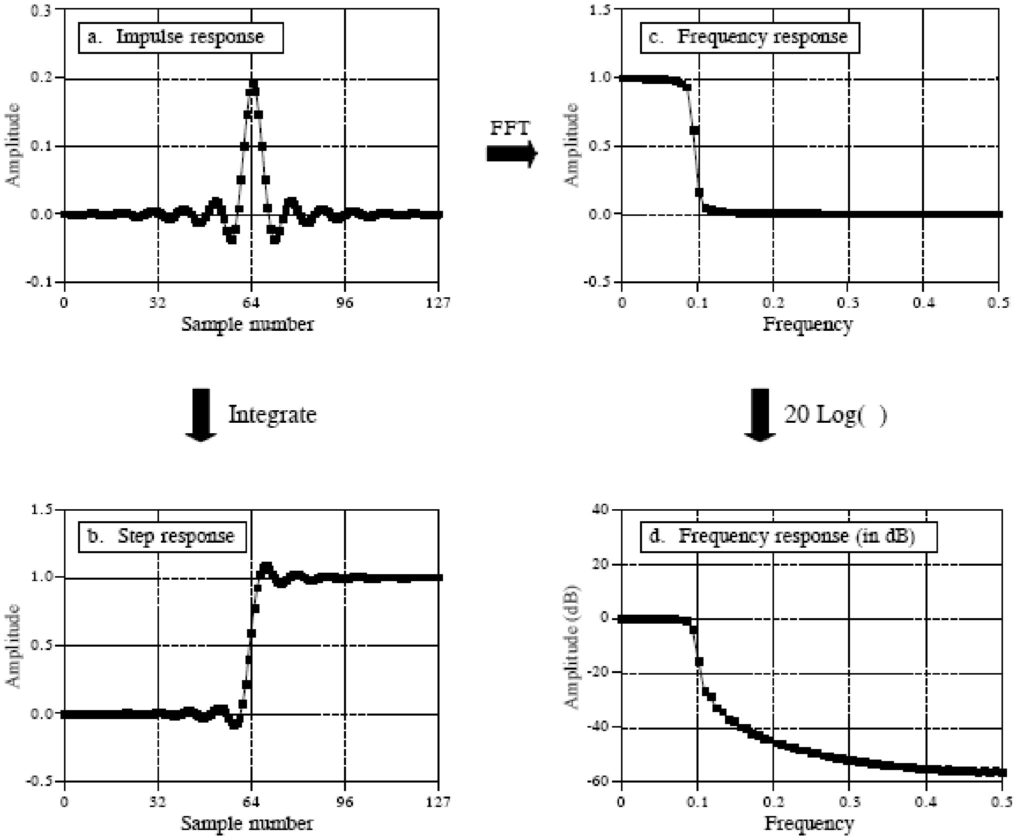


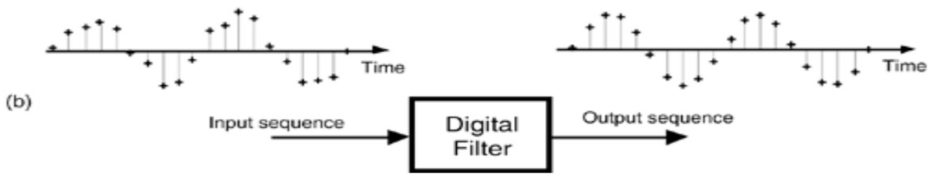
$$A(\omega) = \sum_{n=1}^{M} 2h(M-n)\cos(\omega n) + h(M)$$

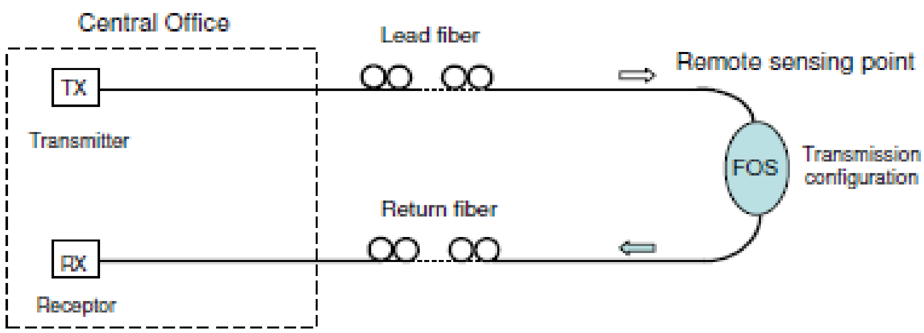


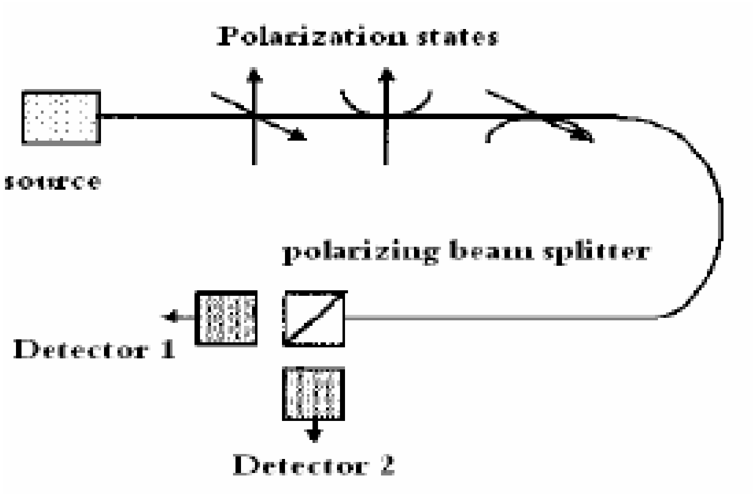
$$y(n) = \sum_{m=0}^{N-1} h(m)x(n-m) \quad H(z) = \sum_{n=0}^{N-1} h(n)z^{(n}$$

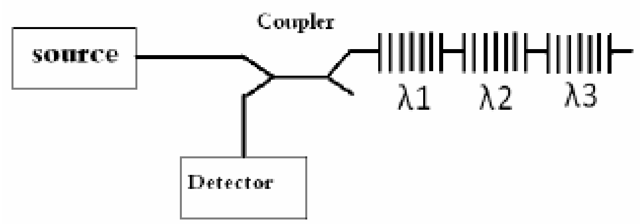


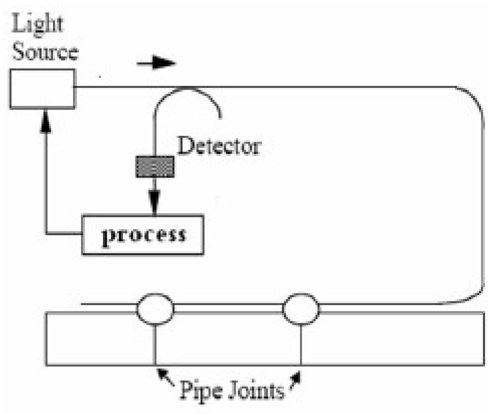

a. Impulse response
Amplitude
Sample number
FFT
c. Frequency response
Frequency
Integrate
20 Log( )
b. Step response
d. Frequency response (in dB)
Amplitude (dB)

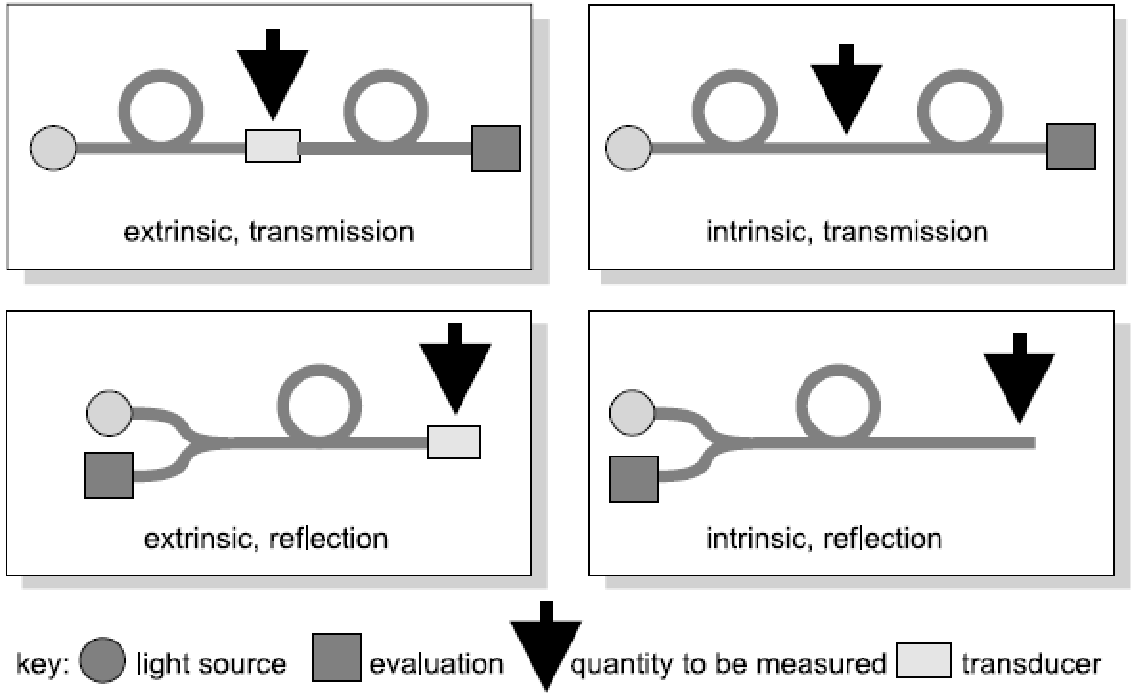

(b)
Time
Input sequence
Digital Filter
Output sequence

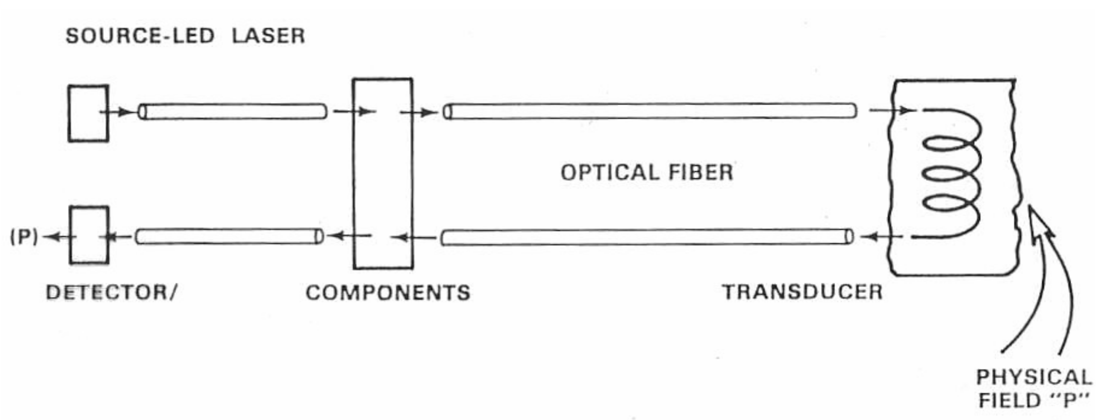

Central Office
TX
Transmitter
RX
Receptor
Lead fiber
Return fiber
Remote sensing point
FOS
Transmission configuration


Polarization states
source
polarizing beam splitter
Detector 1
Detector 2

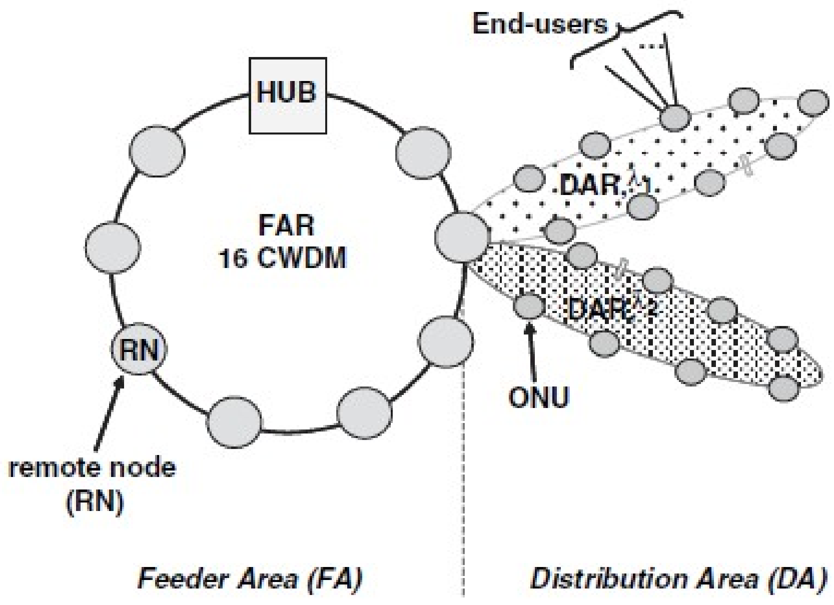

Coupler
source
λ1
λ2
λ3
Detector

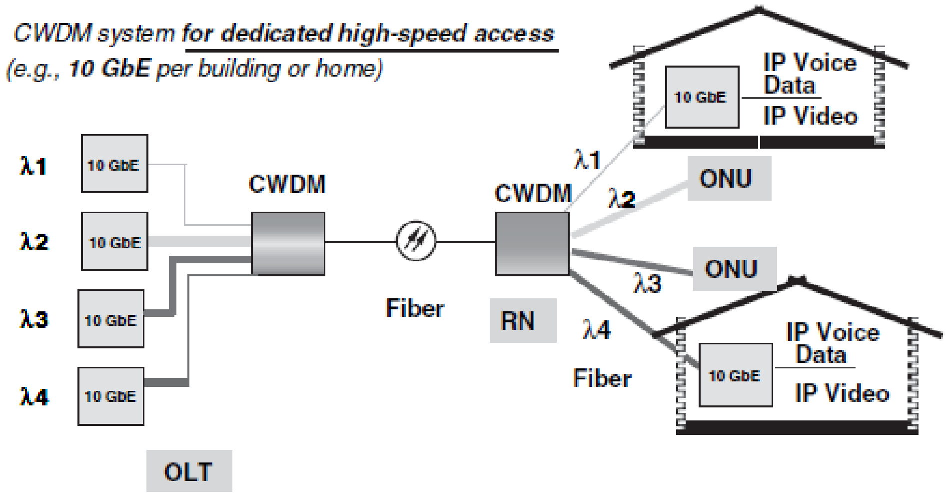

Light Source
Detector
process
Pipe Joints

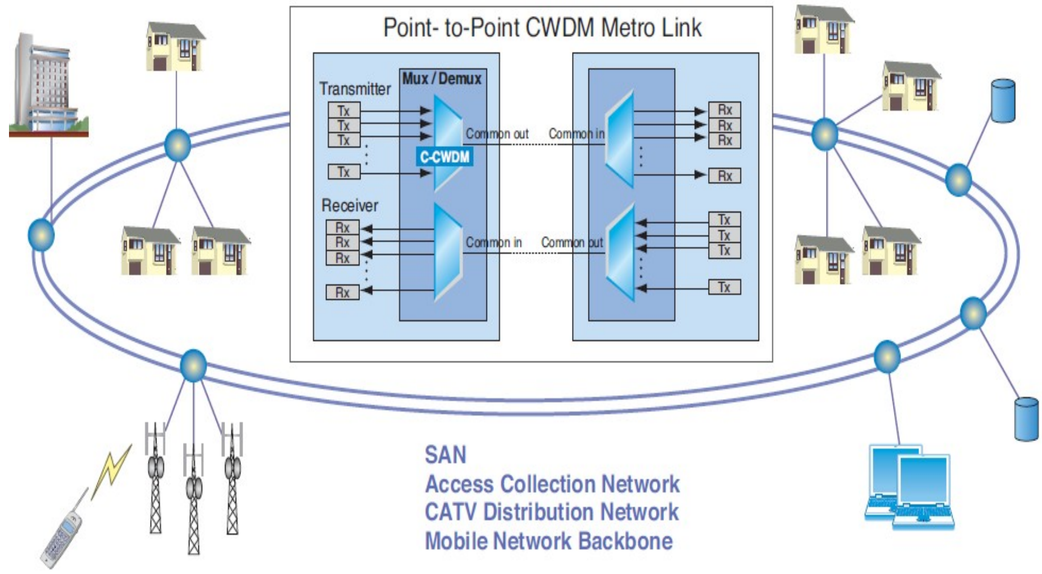

extrinsic, transmission
intrinsic, transmission
extrinsic, reflection
intrinsic, reflection
key:
light source
evaluation
quantity to be measured
transducer

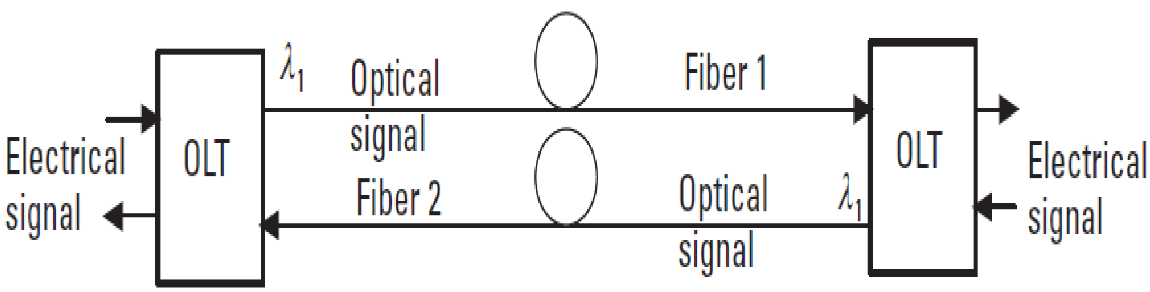

SOURCE-LED LASER
OPTICAL FIBER
(P)
DETECTOR/
COMPONENTS
TRANSDUCER
PHYSICAL
FIELD "P"

	DWDM	CWDM
Transmitter Board Area:	**100 cm.² (16 in.²)**	**20 cm.² (3.1 in.²)**
Laser Footprint:	**Cooled laser** 4 cm. long, 2 cm. high, 2 cm. wide.	**Uncooled laser (TOSA)** 2 cm. long, 0.5 cm. in diameter.
Package Features :	- Butterfly package (or) - Dual inline laser package - Laser die - monitor photodiode - Thermister - Peltier cooler	- Laser die - monitor photodiode - Mounted in a hermetically sealed metal container with a glass window.




CWDM system for dedicated high-speed access
(e.g., 10 GbE per building or home)
λ1
λ2
λ3
λ4
10 GbE
CWDM
Fiber
CWDM
RN
λ1
λ2
λ3
λ4
ONU
ONU
Fiber
IP Voice
Data
IP Video
OLT


Point- to-Point CWDM Metro Link
Transmitter
Mux / Demux
C-CWDM
Receiver
Common out
Common in
Tx
Rx
SAN
Access Collection Network
CATV Distribution Network
Mobile Network Backbone


Electrical signal
OLT
λ1
Optical signal
Fiber 1
Fiber 2
Optical signal
λ1
OLT
Electrical signal

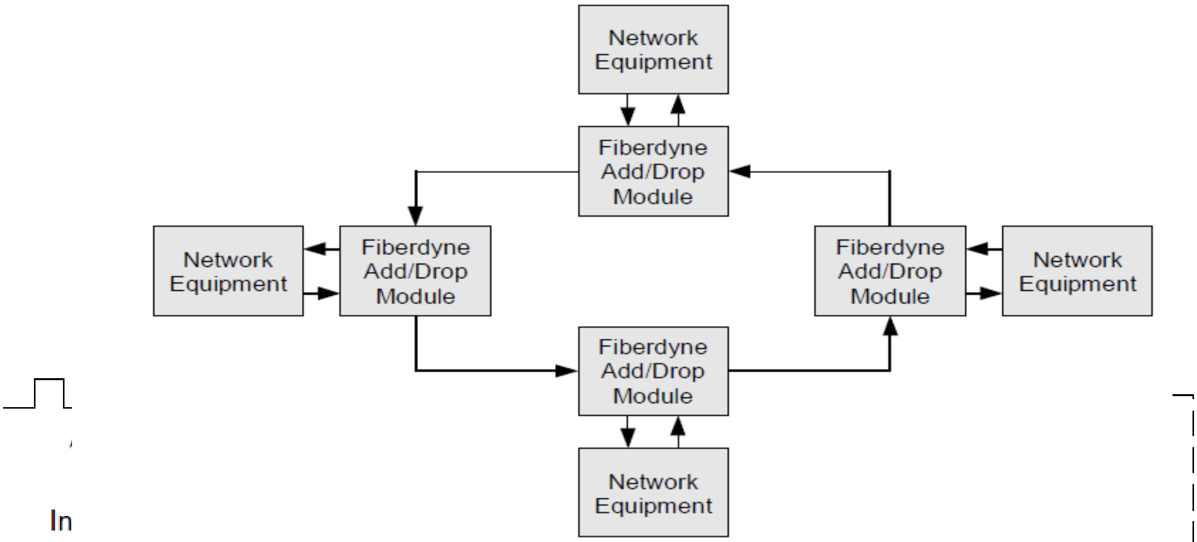


Figure 5: Add/Drop Loop Multiplexer Network

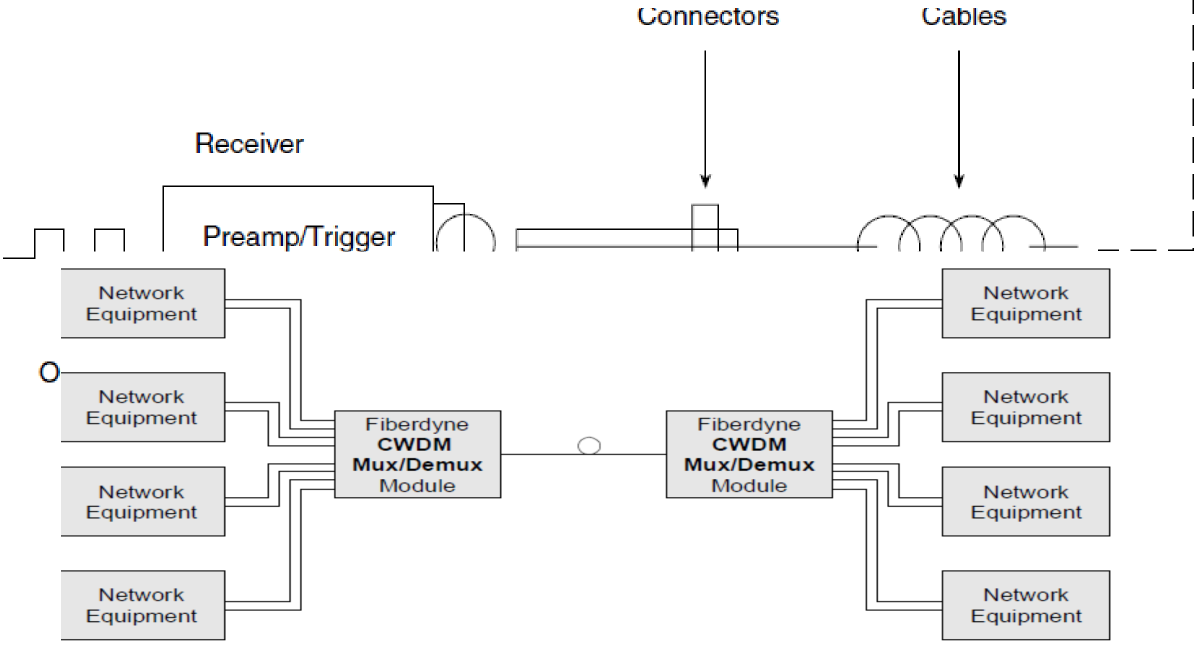
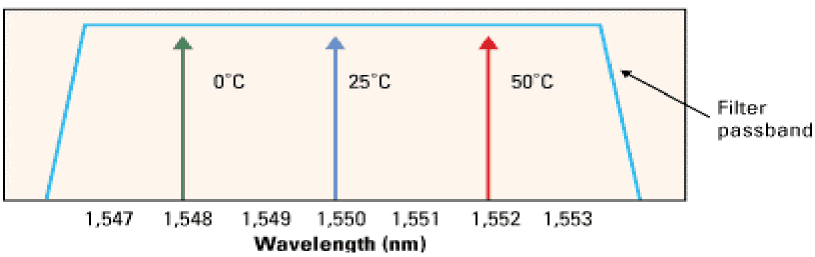
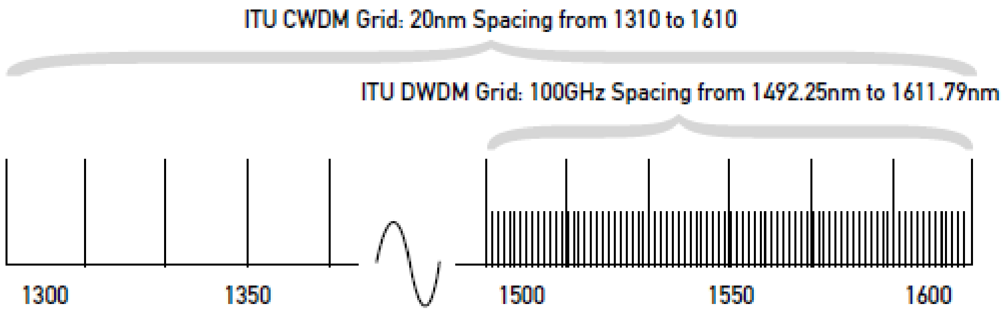
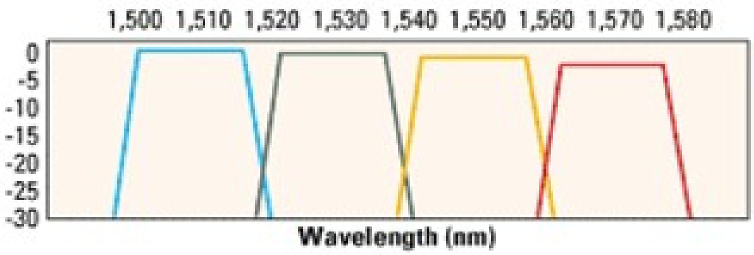


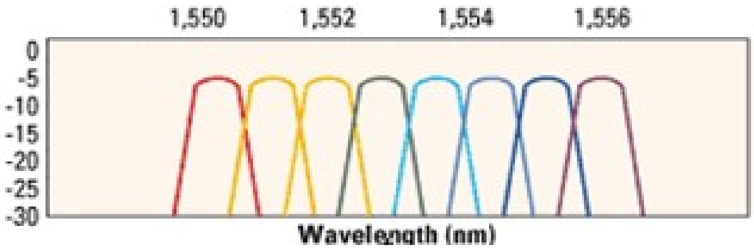
Figure 4: Point-to-point Multiplexer Network

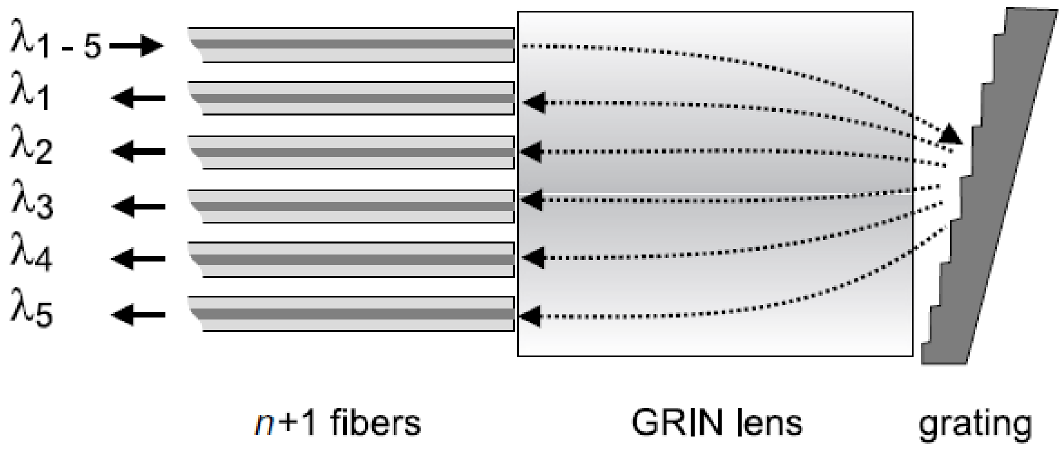
Uncooled 1,550-nm distributed-feedback laser
(wavelength as a function of temperature)

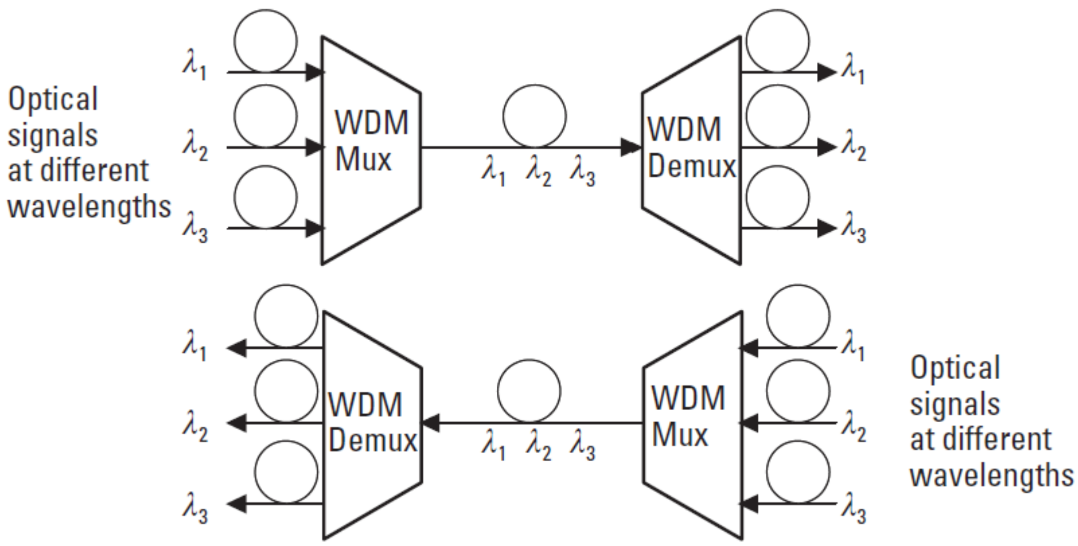


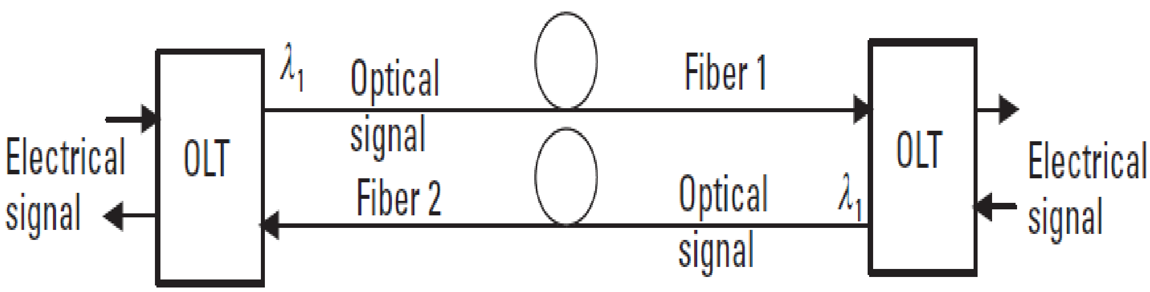

ITU CWDM Grid: 20nm Spacing from 1310 to 1610
ITU DWDM Grid: 100GHz Spacing from 1492.25nm to 1611.79nm
1300
1350
1500
1550
1600

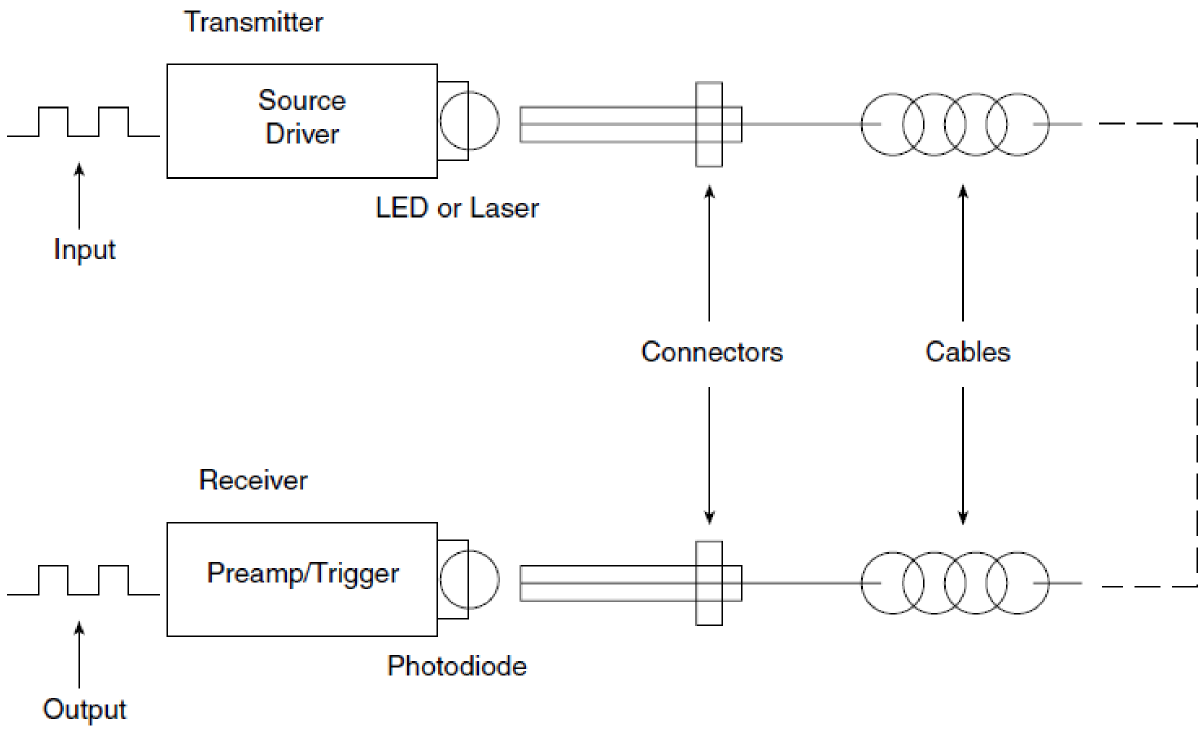

1,500 1,510 1,520 1,530 1,540 1,550 1,560 1,570 1,580
0
-5
-10
-15
-20
-25
-30
Wavelength (nm)


1,550
1,552
1,554
1,556
0
-5
-10
-15
-20
-25
-30
Wavelength (nm)


λ1 - 5
λ1
λ2
λ3
λ4
λ5
n+1 fibers
GRIN lens
grating


Optical
signals
at different
wavelengths
λ1
λ2
λ3
WDM
Mux
λ1 λ2 λ3
WDM
Demux
λ1
λ2
λ3
λ1
λ2
λ3
WDM
Demux
λ1 λ2 λ3
WDM
Mux
λ1
λ2
λ3
Optical
signals
at different
wavelengths


Electrical
signal
OLT
λ1
Optical
signal
Fiber 1
Fiber 2
Optical
signal
λ1
OLT
Electrical
signal



Chapter One

Introduction

:Preface 1.1

Telecommunications use optical techniques in which a carrier wave belongs to a classical optical domain. The wave modulation allows transmitting of analog or digital signals up to a few gigabits per second on a camer of very high frequency, typically 186 to 196 THz. In fact, the bit rate can be further increased using several camer waves that are propagating without a significant interaction on the same fiber. It is obvious that each frequency corresponds to a different wavelength. This technique is called a frequency division multiplexing (FDM) or a wavelength division .[multiplexing (WDM) [l

A goal of any WDM system is to multiply an optical fiber's transmission capacity by sending signals simultaneously at multiple wavelengths. A maximum data rate possible on optical channels depends on the modulation bandwidth of a transmitter source and the width of an optical .channel

Wavelength Division Multiplexing is nowadays a mature technique widely .used in the optical network

For long haul and wide area network, the multiplexing is going towards the higher density of carriers and smaller channel separation and thus Dense WDM (or simply DWDM) has been investigated with channel separations as low as 25 GHz. However, this technique requires very well stabilized laser diodes which greatly increase the network cost. For access network and last mile applications, Coarse WDM systems (or simply CWDM) have been adopted to overcome the cost issue as these applications are very cost sensitive. In standard CWDM systems, a channel separation of20 nm is used .and all the range of 1260 to 1620 nm is explored

CWDM has gained prominence in multi-wavelength digital transport architectures because it permits the use of low-cost, un-cooled laser transmitters. Moreover, powering requirements are reduced and reliability is increased compared with DWDM solution. Universal MUX/DMUX module available for 4, 8, 12 or 16 channel. Channels spaced at 20 nm, following the .standard CWDM wavelength grid

:Fiber optic sensor 1.1.1

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensors are used in everyday objects such as touch-sensitive elevator buttons and .lamps which dim or brighten by touching the base

The fiber optic sensor is one of the most interesting and developing field. It becoming day by day more attractive over other sensors, due to immune to electromagnetic interference (EMI), non-electrical, high accuracy, easy to install, explosion proof small size and weight, the fiber optic replaces other sensors. A number of varieties of parameters like temperature, humidity, pressure, pH, chemical concentration and displacement can be measured .accurately

:Sensor network in CWDM 1.1.2

The goal of any multiplexing architecture, is to connect a number of sensors to a single reading. These sensor can be addressed either .simultaneously or sequentially

CWDM provide many advantages, low insertion losses implemented in Coarse Wavelength Division Multiplexing , it allows obtaining remote self-referenced measurements with a full-duplex fiber downloads up to 35 km long , Low-cost off-the-shelf devices in CWDM technology can be used to .implement and scale the network

As we say above these fiber optic intensity sensors can be easily integrated in WDM networks, including those based on Fiber Bragg Gratings (FBG) operating in reflective configuration for remotely addressing multiple sensing points and providing an effective strategy for exploiting fiber links with a single fiber lead. However, the main drawback of these intensity-based optical sensors is interference from variation in losses non-correlated to the sensor modulation, so some strategy must be integrated in the sensor network or, recently, even integrated in the remote sensing point to overcome those .undesirable power fluctuations

Different configurations providing self-referencing techniques to solve this disadvantage have been reported employing all-optical layouts in the sensor-head with interferometric schemes such as Michelson, Sagnac, Ring resonators schemes or non compact fiber delay coils, emplaced at each sensing point and this fiber delay coils at each sensing points must be identical at the transmission stage for all the sensors; otherwise the operation point of the measurement technique would be different for each sensor, is not desirable situation. Also this technique increases the cost significantly furthermore; this configuration does not reduce the number of optical .connection between the sensors and the reading units

:Objective 1.2

Design the novel electro-optical fiber-optic self referencing CWDM intensity sensor network to achieve compact sensing point with no needed to fiber delay coil ,flexible and re-configurable operation point for each sensor and arbitrary modulation frequencies which it is needed only one modulation frequency of values that can be chosen for appreciate application, furthermore, avoidance of crosstalk that caused by adjacent two CWDM .channels

:Problem statement 1.3

In the previous CWDM optical fiber intensity sensors, fiber delay coils at each sensing points must be identical at the transmission stage for all the sensors; otherwise the operation point of the measurement technique would be different for each sensor, is not desirable situation. Also this technique increases the cost significantly furthermore; this configuration does not reduce the number of optical connection between the sensors and the reading units

:Proposed solution 1.4

To overcome this restriction, is to replace the fiber delay coils with electrical FIR filter with low electrical phase-shift at the reception stage to .obtain a novel electro-optical topology of the remote sensor network

:Methodology 1.5

Design a novel self-referenced CWDM fiber-optic intensity sensor network with a reflective star topology for multiplexing and interrogation of N remote sensing points ,Simulating some critical parameters of the network by using optisystem version7 software and simulation results are presented, .showing the characterization of the network performance

:Thesis lay out 1.6

Chapter one is the introduction of this work, then chapter two is theory which it explain the characterizations of (CWDM), fiber optic sensor and Finite Impulse Response(FIR) filter .Chapter three contain the design and analysis of the proposed configuration. The simulation and results obtained are also given in this chapter. Chapter four includes conclusion and .recommendation

Chapter two

Literature Review

:Introduction 2.1

Optical fiber is the medium in which communication signals are transmitted from one location to another in the form of light guided through thin fibers of glass or plastic. These signals are digital pulses or continuously modulated analog streams of light representing information. These can be voice information, data information, computer information, video .information, or any other type of information

These same types of information can be sent on metallic wires such as twisted pair and coax and through the air on microwave frequencies. The reason to use optical fiber is because it offers advantages not available in any .metallic conductor or microwaves

The main advantage of optical fiber is that it can transport more information longer distances in less time than any other communications medium. In addition, it is unaffected by the interference of electromagnetic radiation, making it possible to transmit information and data with less noise and less error. There are also many other applications for optical fiber that are simply not possible with metallic conductors. These include sensors/scientific applications, medical/surgical applications, industrial applications, subject .illumination, and image transport

Most optical fibers are made of glass, although some are made of plastic. For mechanical protection, optical fiber is housed inside cables. There are many types and configurations of cables, each for a specific application: .indoor, outdoor, in the ground, underwater, deep ocean, overhead, and others

An optical fiber data link is made up of three elements show in figure (2.1) first a light source at one end (laser or light-emitting diode [LED]), including a connector or other alignment mechanism to connect to the fiber. The light source will receive its signal from the support electronics to convert the electrical information to optical information. then The fiber (and its cable, connectors, or splices) from point to point. The fiber transports this light to its .destination

Finally the light detector on the other end with a connector interface to the fiber. The detector converts the incoming light back to an electrical signal, producing a copy of the original electrical input. The support electronics will .[process that signal to perform its intended communications function [1

Figure (2.1): A typical fiber optic data

:Multiplexing and Demultiplexing 2.1.1

In order to maximize the information transfer over an optical fiber communication link it is usual to multiplex several signals onto a single fiber. In telecommunications and computer networks, multiplexing (also known as muxing) is a process where multiple analog message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource. For example, in telecommunications, several phone calls may be transferred using one wire. It originated in telegraphy, and is now widely applied in communications. The multiplexed signal is transmitted over a communication channel, which may be a physical transmission medium. The multiplexing divides the capacity of the low-level communication channel into several higher-level logical channels, one for each message signal or data stream to be transferred. A reverse process, known as demultiplexing, can extract the original channels on the receiver side. A device that performs the multiplexing is called a multiplexer (MUX), and a device that performs the reverse process is called a demultiplexer [(DEMUX).[23

Several techniques can be used to improve the use of a communication channel, Time Division(TDM) , Frequency Division Multiplexing(FDM) and in optical fiber optical systems transmit light energy pulses to the fiber; they do not use light as a carrier the same way as in radio communications. In bidirectional systems two fibers, one for each transmission direction, are needed as shown in Figure (2.2). However, development of semiconductor laser technology has made narrow bandwidth lasers available and several parallel optical signals at different wavelengths can use the same fiber. This wavelength-division multiplexing (WDM) uses an optical coupler to combine optical signals (WDM multiplexer) and optical filters (WDM demultiplexer) .[to separate optical signals at the receiving end as shown in Figure (2.3)[7

Figure(2.2): Optical fiber system

:(Wavelength Division Multiplexing (WDM 2.1.1.1

Many single-mode fiber cables have been installed and technical solutions that increase fiber capacity without installation of new cable have become very attractive as the demand for transmission capacity increases. Particularly in long-distance systems, wave length division multiplexing (WDM) has become popular and it can increase fiber capacity by a factor [From 10 to 100.[7

Wavelength Division Multiplexing (WDM) is a method of transmitting data from different sources over the same fiber optic link at the same time whereby each data channel is carried on its own unique wavelength. The result is a link with an aggregate bandwidth that increases with the number of wavelengths employed. In this way WDM technology can maximize the use of the fiber optic infrastructure that is available; what would normally require .two or more fiber links instead requires only one

(Figure (2.3): wave length division multiplexing (WDM

(Figure (2.4): Basic idea of a wavelength-dependent coupler (WDM coupler

:WDM Applications 2.1.1.2

There are several application of wavelength division multiplexing (WDM) like reduction of chromatic dispersion when light emitting diodes are used. also it used for transmission protection, also wavelength division multiplexers are very useful for chromatic dispersion measurement of fiber link also it used in industrial control and sensor network. The wavelength division multiplexing can be used in telespectroscopy and multiplexing of .radar signal

:2.1.1.3WDM Advantages

The same advantages apply equally in the case of access systems, making the future expansion of system capacity an inexpensive proposition. WDM can be used in access networks as an economical means of boosting transmission capacity by adding different wavelength transceivers, but it also promises economic benefits in other areas. For instance, if demand for Internet services is accompanied by demand for video and other content delivery services, these new services can be accommodated on new wavelengths over the existing optical fiber. It is also possible to allocate separate wavelengths to users who require greater transmission capacity. In this way, WDM represents an economical way to utilize existing networks, allowing the flexibility to upgrade performance and functionality by increasing capacity and providing new services. Thus, WDM makes maximum use of existing networks and equipment, and provides an economical means of delivering advanced services simply by upgrading terminals as required. The underlying system concept presupposes compatibility with existing networks and equipment. Next, we consider economic and ease of handling issues as regards WDM equipment and .[components [5

:Limitations 2.1.1.4

With many advantages of wavelength division multiplexing (WDM), there are few drawbacks like crosstalk effects, polarization effect in multi/demultiplexers, crosstalk due to Raman conversion, also crosstalk due to other non-linear effects and some other limitations due to beat interference in wavelength division, also in few cases spectral changes can be induced by the state of coherence of sources. This may explain residual crosstalk .[problems in specific situations [8

:2.1.1.5WDM Types

Wavelength Division Multiplexing (WDM) comes in two flavors coarse wavelength multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM) they are both mature WDM technologies, using standardized ITU-T wavelengths. coarse wavelength multiplexing CWDM systems were devised as a low-cost solution in Metropolitan Area Network where the customer is expected to pay for broadband services with an affordable price. The laser sources deployed in such systems are not thermally cooled and so the emission wavelength is allowed to drift within ± 6.5 nm around the nominal central wavelength. In contrast, DWDM systems deploy very stable laser sources and thus the cost of these systems is four to five times larger than their CWDM counterparts. In CWDM networks, the channels are spaced apart by 20 nm which is in contrast to DWDM systems where the channels are spaced apart by 0.1 nm. This basic difference is the problematic issue in CWDM systems as the bandwidth to be multiplexed is large. This bandwidth stands as an obstacle against the adaptation of the readily developed WDM designs for CWDM systems, since the bandwidth offered by most of the optical components do not comply with this large bandwidth requirement, which is 80 nm for a 1x4 design and 160 nm for a 1x8 design [9]. In general, DWDM is the best choice for applications where channel density/bandwidth is of high priority. At the same time, CWDM remains an excellent option for applications where deployment costs are to be considered. Figure (2.5) shows typical transmittance for a four-channel CWDM and typical transmittance for an eight-channel DWDM. ITU .((DWDM and CWDM) grid shown in figure(2.6

Figure (2.5): coarse WDM vs. Dense wavelength demultiplexer

Figure (2.6):ITU (DWDM and CWDM) grid

:CWDM 2.2

Coarse wavelength-division multiplexing (CWDM) technology was first commercially deployed in the early 1980s for transporting digital video signals over multimode fiber. CWDM is becoming more widely accepted as important transport architecture. Unlike DWDM, systems based on CWDM technology deploy uncooled distributed-feedback (DFB) lasers and wideband optical filters. These technologies provide several advantages to CWDM systems such as lower power dissipation, smaller size, and less cost. The commercial availability of CWDM systems offering these benefits makes the technology a viable alternative to DWDM systems for many metro and access applications. Figure (2.7) Coarse WDM lasers drift in wavelengths uncooled at the rate of approximately 0.08nm/c (wavelength as a function of .(temperature

Figure (2.7): Uncooled 1,550-nm distributed-feedback laser

Coarse WDMs perform two functions. First, they filter the light, ensuring only the desired wavelengths are used. Second, they multiplex or demultiplex multiple wavelengths, which are used on a single fiber link. The difference lies in the wavelengths, which are used. In CWDM space, the 1310-band and the 1550-band are divided into smaller bands, each only 20-nm wide. In the multiplex operation, the multiple wavelength bands are combined (i.e. muxed) onto a single fiber. In a demultiplex operation, the multiple wavelength bands are separated (i.e. demuxed) from a single fiber. The used wavelengths are defined by the International .Telecommunications Union; reference ITU G.694.2 for the ITU CWDM Wavelength Grid. Note: as of June 2002, eighteen center wavelengths, from 1270 nm to 1610 nm, were listed. end, transmit signals are muxed, while receive signals are demuxed. For example, in a simple full-duplex link, the transmit is assigned the 1530-.nm wavelength, while the receive signal is assigned the 1550-nm wavelength

:2.2.1CWDM Applications

Generally, a CWDM network takes two forms. A point-to-point system connects two locations, muxing and demuxing multiple signals on a single (fiber (see Figure below

Figure (2.8): Point-to-point Multiplexer Network

or multi-point system connects multiple locations, typically using Add/Drop .(modules (see Figure below

Figure (2.9): Add/Drop loop Multiplexer Network

Also CWDM networks have been proposed for use in other applications such as metro access, x-PON and storage area networks (SAN) .[see figure below [9

Figure (2.10): Point-to- point CWDM Metro Link

Today, some new application areas for CWDM links are getting hot.
One is the WDM passive optical network (PON) system, which is a point-to-multipoint subscriber access network and provides higher bandwidth than PONS based time-division-multiplexing technology. Figure (2.11) shows an example of CWDM PON architecture where specific wavelength targeted to each Optical Network Units (ONU) with high bandwidth. The case of 10 GbE . data is shawn

Figure (2.11): CWDM system 10 GbE per building or home

An example of this is a double CWDM Ring network [5] where a packet-oriented optical access network is considered which can deliver bandwidths of 25 Mb/s (mean) to 100 Mb/s (peak) to an average end-user. It can also accommodate high-end customers with higher bandwidth demands. It is assumed that the optical access network area consists of two major parts: Feeder Area (FA), covering the section between central office (CO) and splitting nodes (remote nodes, RN) placed in the field. The second section is the Distribution Area (DA) for linking customer's premises to the FA. Both parts of the network consist of ring structures figure (2.12). An example with eight RNs is shown, where the CWDM system is completely exploited by two .wavelengths per RN Studied CWDM double ring network concept

Figure (2.12): CWDM ring structure

:CWDM Benefits 2.2.4

The market for coarse wavelength division multiplexing (CWDM) links is broadening. So far, the main market for such links is the metro network. This is because a CWDM system can carry enough bandwidth for multiple metro applications and is less expensive than a dense-WDM

(DWDM) system, which requires costly light sources with thermal controllers .and expensive optical filters with high wavelength accuracy

Also CWDM systems offer significant advantages over the more conventional dense wavelength-division multiplexing (DWDM) networks for aerospace applications. In DWDM, the spacing between adjacent channels is typically <1nm, whereas the CWDM standard is 20nm channel spacing. By exploiting this WDM standard, the requirement for an optical source to transmit at a specific, well-defined wavelength is somewhat relaxed, enabling a degree of centre wavelength drift with temperature to be tolerated – the CWDM standard defines a 13nm filter bandwidth. This promises significant reductions in device cost, weight, volume and power consumption, since it may be possible to use un-cooled laser sources. However, this assumes that the CWDM filter technology is stable over the aerospace operating conditions. The price of DWDM transceivers is typically four or five times more expensive than that of their CWDM counterparts. The higher DWDM transceiver costs are attributed to a number of factors related to the lasers. The manufacturing wavelength tolerance of a DWDM laser die compared to a CWDM die is a key factor. Typical wavelength tolerances for DWDM lasers are on the order of ±0.1 nm; whereas tolerances for CWDM laser die are ±2-3 nm. Lower die yields also drive up the costs of DWDM lasers relative to CWDM lasers. In addition, packaging DWDM laser die for temperature stabilization with a Peltier cooler and thermister in a butterfly package is more expensive than the uncooled CWDM coaxial laser packaging. The cost difference between DWDM and the CWDM multiplexers and demultiplexers contributes to lower overall system costs in favor of CWDM as well. CWDM filters are inherently less expensive to make than DWDM filters due to the fewer number of layers in the filter designs. Typically, there are approximately 150 layers for 100-GHz filter designs used in DWDM systems, whereas there are approximately 50 layers in a 20-nm, CWDM filter. The .result is higher manufacturing yields for CWDM filters

:Power Requirements 2.2.4.1

Issue for board designers, the lower power requirement resulting from the use of uncooled lasers in CWDM systems has positive financial implications for system operators. For example, the cost of battery backup is a major consideration in the operation of transport equipment. Minimizing operating power and the costs associated with its backup, whether in a central .office or a wiring closet, reduces operating costs

:Physical Size 2.2.4.2

CWDM lasers are significantly smaller than DWDM lasers. Uncooled lasers are typically constructed with a laser die and monitor photodiode mounted in a hermetically sealed metal container with a glass window. These containers are aligned with a fiber pigtail or an alignment sleeve that accepts a connector. The container plus sleeve forms a cylindrical package called a Transmitter Optical Subassembly (TOSA). A typical TOSA is approximately 2 cm long and 0.5 cm in diameter. Cooled lasers are offered in either a butterfly or dual inline laser package and contain the laser die, monitor photodiode, thermister, and Peltier cooler. These lasers are about 4 cm long, 2 cm high and 2 cm wide. These devices are almost always pigtailed, requiring fiber management, a heatsink, and corresponding monitor and control circuitry. The size of a DWDM laser transmitter typically occupies about five times the board area of a CWDM transmitter, i.e., 100 cm2 (16 in.2) compared to a CWDM transmitter with an uncooled laser occupying 20 cm2 .((3.5 in.2

Table (2.1) :CWDM vs DWD

:Reliability 2.2.4.3

The reliability of DFB lasers used in DWDM and CWDM transport systems has been proved in both cooled and uncooled designs. The difference between the two laser designs is the number of additional components, including the Feltier cooler, Thermister, and associated electronics in DWDM lasers. However, this author has no data to substantiate a significant reliability difference between the two types of systems in real world applications. Further analysis may or may not suggest otherwise. Up to 16 Wavelengths CWDM systems supporting two to eight wavelengths are commercially available today. These systems are anticipated to scale to 16 wavelengths in the 1,290-1,610-nm wavelength region in the future. Today, most CWDM systems are based on 20-nm channel spacing from 1,470 to 1,610 nm, with .some development occurring in the 1,300-nm window

Wavelengths in the 1,400-nm region suffer higher optical signal loss due to the attenuation peak caused by residual water present in most of the installed fiber. While this additional loss can limit system performance for longer links, it is not a major obstacle to CWDM deployment in most metro access spans CWDMA/OCDMA PONs: Coarse WDM (CWDM) allows low-cost WDM to be deployed (as device cooling is not required); CWDM uses channel spacing of 20 nm, so only eight or so channels can normally be deployed. OCDMA as a robust complementary technology that could also be deployed in conjunction with CWDM to increase the number of users. As with WDM, OCDMA offers the possibility of translation from one channel to .another (code translation), opening many interesting possibilities

:Fiber Optic Sensor 2.3

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument. Sensors are used in everyday objects such as touch-sensitive elevator buttons and lamps which dim or brighten by touching the base. The fiber optic sensor is one of the most interesting and developing field. The technology and applications of optical fibers have progressed very rapidly in recent years. Optical fiber, being a physical medium, is subjected to perturbation of one kind or the other at all times. It therefore experiences geometrical (size, shape) and optical (refractive index, mode conversion) changes to a larger or lesser extent depending upon the nature and the magnitude of the perturbation. An optical fiber sensing system is basically composed of a light source, optical fiber; a sensing element or transducer and detector it shown in .(figure (2.13

Figure (2.13): fiber optic sensor system

:Benefits and Advantages 2.3.1

Optical fiber sensors offer attractive characteristics that make them very suitable and, in some cases, the only viable sensing solution. Fiber optic intensity sensors can operate at hostile and flammable environments because they are intrinsically safe and immune to electromagnetic interference (EMI). Additionally, they can be easily integrated in WDM networks and commercial devices and laboratory prototypes are available for the measurement of several magnitudes such as ultrasonic, temperature, pressure, humidity, corrosion and displacement. In general, Fiber Optic Sensor(FOS) is characterized by high sensitivity when compared to other types of sensors. It is also passive in nature due to the dielectric construction. Specially prepared fibers can withstand high temperature and other harsh environments. In telemetry and remote sensing applications it is possible to use a segment of the fiber as a sensor gauge while a long length of the same or another fiber can convey the sensed information to a remote station. Deployment of distributed sensors covering extensive structures and geographical locations is .also feasible

:Classification 2.3.2

There are a variety of fiber optic sensors. These can be classified as :follows

Based on the modulation and demodulation process a sensor can be called as intensity (amplitude), a phase, a frequency, or a polarization sensor. Since detection of phase or frequency in optics calls for interferometric techniques, .the latter is also termed as an interferometric sensor

Fiber optic sensors can also be classified on the basis of their application: physical sensors (e.g. measurement of temperature, stress, etc.); chemical sensors (e.g. measurement of pH content, gas analysis, spectroscopic studies, etc.); biomedical sensors (inserted via catheters or endoscopes which measure blood flow, glucose content and so on). Both the intensity types and the interferometric types of sensors can be considered in any of the above .[applications [4

Extrinsic or intrinsic sensors are another classification scheme. In the former, sensing takes place in a region outside of the fiber and the fiber essentially serves as a conduit for the to-and-fro transmission of light to the sensing region efficiently and in a desired form. On the other hand, in an intrinsic sensor one or more of the physical properties of the fiber undergo a .change as mentioned in above

Fiber optic sensors can also classified in response to their measurements points. The tree important classes here are; point to point sensors, multiplex sensors and distributed sensors. In point to point type there is a single measurement point at the end of the fiber optic connection cable, similarly to most electrical sensors. Multiplexed sensors allow the measurement at multiple points along a single fiber line and Distributed sensors are able to sense at any point along a single fiber line, typically every meter over many .kilometers of length

:Fiber-Optic Sensors Types 2.3.2.1

Divided into two types extrinsic and intrinsic, extrinsic theses sensor are mounted in front of, next to, or in proximity of the fiber, read the quantity under investigation, and launch a corresponding light signal into the fiber. In this case, the fiber is merely the transmission medium and has nothing to do with the acquisition of the original quantity in contrast. Intrinsic sensors use the fiber itself or part of it directly to read the original quantity. Then the fiber is both sensor and cable at the same time. We will look at examples of both types. Classification of sensor types in figure (2.14). In extrinsic sensors (left column), a transducer converts the original quantity to an optical format; in intrinsic sensors (right column) the fiber itself is the transducer. One can also distinguish transmission sensors (top row) and reflection sensors (bottom row). The former are simpler in structure because no couplers are required to separate forward and backward traveling light. The latter are more convenient [to use, though, because only one end of the fiber needs to be accessible.[6

Figure (2.14): Classification of sensor types

:Modulation Based Fiber Optic Sensor 2.3.2.2

These kinds of sensors have four main sub classes. We will discuss about each of them in this section. Intensity Based Fiber Optic Sensor Intensity-based fiber optic sensors rely on signal undergoing some loss. They are made by using an apparatus to convert what is being measured into a force that bends the fiber and causes attenuation of the signal. Other ways to attenuate the signal is through absorption or scattering of a target. The intensity-based sensor requires more light and therefore usually uses multimode large core fibers .There are a variety of mechanisms such as microbending loss, attenuation, and evanescent fields that can produce a measurand-induced change in the optical intensity propagated by an optical fiber. The advantages of these sensors are: Simplicity of implementation, low cost, possibility of being multiplexed, and ability to perform as real distributed sensors. The drawbacks are: Relative measurements and variations in the intensity of the light source may lead to false readings, unless a .referencing system is used

:applications 2.3.3

Fiber optic sensors have been subject to considerable research for the .[past 30 years or so since they were first demonstrated about 40 years ago [2 These new sensing technologies have formed an entirely new generation of sensors offering many important measurement opportunities and great potential for diverse applications. The most highlighted application fields of FOS are in large composite and concrete structures, the electrical power industry, Medicine, Chemical sensing, and The gas and oil industry. Also modulated fiber optic sensor has much application in civil infrastructure, naval vessels, aircraft/space, pipe line monitoring Damage Assessment .Systems and naval vessels

:Multiplexing 2.3.4

In some applications there may be a need for multisensory systems. .Such a system can be realized in a number of ways

One way is to arrange a set of discrete (point) sensors in a network or array configuration, with individual sensor outputs multiplexed. The most commonly employed techniques are time, frequency, wavelength, coherence, .polarization, and spatial multiplexing

:(2.3.4.1Time Division Multiplexing (TDM

Time division multiplexing employs a pulsed light source, launching light into an optical fiber and analyzing the time delay to discriminate between sensors. This technique is commonly employed to support distributed sensors where measurements of strain, temperature, or other parameters are collected illustrates a time division multiplexed system that uses micro bend-sensitive areas on pipe joints. As the pipe joints are stressed, micro bending loss increases and the time delay associated with these losses allows the location of faulty joints. The entire length of the fiber can be made micro bend sensitive and Rayleigh scattering loss used to support a distributed .sensor that will predominantly measure strain

Figure (2.15): Time division multiplexing method

:(Wavelength Division Multiplexing (WDM 2.3.4.2

Wavelength division multiplexing is one of the best methods of multiplexing as it uses optical power very efficiently. It also has the advantage of being easily integrated into other multiplexing systems, allowing the possibility of large numbers of sensors supported in a single fiber line, figure (2.16) illustrates a system where a broadband light source, such as a light-emitting diode, is coupled into a series of fiber sensors that reflect signals over wavelength bands that are subsets of the light source spectrum. A dispersive element, such as grating or prism, is used to separate the signals from the .sensors onto separate detectors

Source

Figure (2.16): Wavelength division multiplexing

Detector

Complex

:Multiplexing Polarization 2.3.4.3

One of the least commonly used techniques is polarization multiplexing. In this case the idea is to launch light with particular polarization states and extract each state. A possible application is shown in figure (2.17) where light is launched with two orthogonal polarization modes; preserving fiber and evanescent sensors have been set up along each of the axes. A polarizing beam splitter is used to .separate the two signals

There is recent interest in using polarization-preserving fiber in combination with time domain techniques to form polarization-based distributed fiber sensors. This has the potential to offer multiple sensing .parameters along a single fiber line

Figure (2.17): Polarization multiplexing remote sensor concept

:There are three ingredients required for any remote sensor concept

Sensors for any physical quantity that may be of interest (temperature, .pressure, strain etc), Transmission lines and Displays

Displays translate the transmitted data into a format accessible to .human senses, i.e., typically make them visible or audible

A general schematic for supporting remote optical intensity sensors is shown in figure (2.18) In this system, the transmission and reception stages are located in a single point, namely Central Office (CO), where the light is launched into a lead fiber towards the remote sensing point, where it passes .through the optical sensor and returns to the CO through a return fiber

(Figure (2.18): Fiber link for remotely addressing fiber-optic intensity sensors (FOS

Remote addressing of photonic sensors uses optical fibers and multiplexing schemes to measure the response of multiple sensing points have .been a motive a research during the last years

:Digital Filters 2.4

Filter is essentially a system or a network that selectively changes the wave shape, amplitude –frequency and\or phase-frequency characteristics of a .signal in a desire manner

In the 1980s, very large-scale integration (VLSI) developments have dramatically reduced the cost and power consumption of digital filters and have led to much more widespread application of digital signal process. Common filtering objectives are to improve the quality of a signal (for example to reduce or remove noise), to extract information from signals or to separate two or more signals previously combined to make ,for example, .efficient use of an variable communication channel

A digital filter, is a mathematical algorithm implement in hardware and/or software that operates on a digital input signal to produce a digital out put signal for a purpose of achieving a filtering objective .The term digital filter refer to specific hardware or software routine that perform filtering .algorithm

Digital filter often operate on digitized analog signals or numbers .representing some variable stored in computer memory

The digital filter in figure (2.19) of course, can be a software program in a computer, a programmable hardware processor, or a dedicated integrated circuit. Traditional linear digital filters typically come in two flavors: finite .[impulse response (FIR) filters and infinite impulse response (IIR) filters [11

Figure (2.19): Basic idea of digital filters

:Filter parameters 2.4.1

Every linear filter has an impulse response, a step response and a frequency response. Each of these responses contains complete information about the filter, but in a different form. If one of the three is specified, the other two are fixed and can be directly calculated. All three of these representations are important, because they describe how the filter will react .[under different circumstances [12

Figure (2.20): Filter parameters

The step response, (b), can be found by discrete integration of the impulse response, (a). The frequency response can be found from the impulse response by using the Fast Fourier Transform (FFT), and can be displayed .(either on a linear scale, (c), or in decibels, (d

The impulse response is the output of a system when the input is an impulse. In this same manner, the step response is the output when the input is a step (also called an edge, and an edge response). Since the step is the integral of the impulse, the step response is the integral of the impulse response. This provides two ways to find the step response: (1) feed a step waveform into the filter and see what comes out, or (2) integrate the impulse response. (To be mathematically correct: integration is used with continuous signals, while discrete integration, i.e., a running sum, is used with discrete signals). The frequency response can be found by taking the DFT (using the .FFT algorithm) of the impulse response

A digital filter is a stationary linear system (SLS) with sampled time (TS). h .([[n] is the response of the system to an impulsive input (δ[n

:(Finite Impulse Response filters (FIR 2.4.2

Digital filters are broadly divided into two classes namely infinite .(impulse response (IIR) and finite impulse (FIR

FIR digital filters use only current and past input samples, and none of the filter's previous output samples, to obtain a current output sample value. (That's also why FIR filters are sometimes called nonrecursive filters.) Given a finite duration of nonzero input values, the effect is that an FIR filter will always have a finite duration of nonzero output values, and that's how FIR .filters got their name

Either type of filter in it's basic form can represented by its impulse response, h (k) (m = 0, 1, 2,…). The input and out put signals to the filter related by the convolution sum, which given in equation below

m=0,1,…,N-1

The impulse response is of finite duration h(m) is very important of most filter design problems. The alternative representation for FIR is given in equation below

It is the transfer function for FIR filter and it is very useful in evaluating their frequency response .N is the filter length, that is the filter .coefficients

FIR filter is usually implemented by using series of delay of delays, .multipliers, and adder to create the filters out put

In figure (2.21) shows the basic block diagram for an FIR filter of length N. The delays result in operating on prior input samples. The h(k) (k=0,1,…N-1), values are the coefficients used for multiplication, so that the output at time n is the summation of all the delayed samples multiplied by the .appropriate coefficients

Figure (2.21): The logical structure of FIR filter

:Characteristics of FIR Filterers 2.4.2.1

FIR filter can have exactly linear phase response, that mean no phase distortion introduce into the signal by the filter. This is important requirement .in many applications, for example data transmission

Fir filters realized non recursively, they are always stable. The effect of using a limited number of bits to implement filters round off noise and coefficient quantization is more less. FIR filters are very simple implement have been used when the number of filter coefficient is not too large and in particular if letter of phase distortion is desired, that mean the FIR filters is .more efficient

:Linear Phase Response 2.4.2.1.1

The most important property of FIR filters that, When a signal passes through a filter, it is modified in amplitude and/or phase. The nature and extent of the modification of the digital is dependent on the amplitude and phase characteristics of the filter the phase delay or group of phase delay of the filter provides a useful measures of how filters modifies the phase characteristics of the signal. If the signal consists of several frequency the phase delay of the filter is the amount of delay of each frequency component :of the signal suffers at each side Mathematically

$$T_p = -\theta(\omega)/\omega$$

$$T_e = -d(\omega)/d\omega$$

:Where

T_p :is the phase delay

is the phase angle (ω)

:The frequency response

:FIR filter types 2.4.2.2

There are four possible types of FIR Filters leading to the linear phase, odd-even, even-even, odd-odd, and even-odd, are shown in figure (2.22)a, b, .c and d respectively

The first type(odd-even), it's impulse response which has odd length and it has even symmetric about its midpoint n = M = (N - 1)/2, which requires (h(n) = h (N - n - 1

.Figure (2.22a):odd-even

Type tow(odd-odd**),** it's impulse response which has even length and it has even symmetric about M, but M is not an integer. Therefore, there is no .h(n) at the point of symmetry, but it satisfies

.Figure (2.22.b):even-even

Type three(odd-odd), it's impulse response which has odd length and it has odd symmetry of giving an imaginary multiplier for the linear-phase form :in

(h(n) = - h(N- n -1

.Figure (2.22.c):odd-odd

Type four**(**even-odd**),** it's impulse response which has even length and it has .odd symmetry of type three

(h(n) = - h(N- n -1

For N even

.Figure (2.22.d):even-odd

:Averaging filter 2.4.2.3

FIR filters use addition to calculate their outputs in a manner much the same as the process of averaging uses addition. In fact, averaging is a kind of FIR filter that can be illustrated with an example in figure (2.23) is the averaging filter block diagram when the fifth input samples (37, 42, 24, 22, 10) are .[applied [11

Figure (2.23): Averaging filter block diagram

:FIR Filter Design 2.4.2.4

:The design of digital filter involves five steps

Filter specification, Coefficient calculation, Realization, Analysis of .finite word length and Implementation

:Coefficient Calculation 2.4.2.5

The object of FIR coefficient calculation is to obtain value of h (n).There are several method of calculating the coefficient of FIR filter are .window method, the optimal method, frequency sampling method and other

:FIR Implementation Techniques 2.4.2.6

It is the final stage of designing filter, and the key issue here is essentially to produce software code and/or hardware realization of the chosen :filter structure. To implement a filter, the basic components that needed are
Memory (RAM) to store the present and past input samples. X(n) and x(n-.(k
Memory (RAM or ROM) for storing the filter coefficients, the h (k) and a .(multiplier (software or hardware); adders or arithmetic logic unit (ALU
These components together with a means of controlling them constitute the digital filter. If the source of the input data is analog, then an ADC is needed as well. Similarly, if the output is analog. The filter implementation is by tradition divided into two parts, hardware and software. Hardware implementation is offers the greatest speed, but is less flexible. The three approaches in hardware implementations: standard microprocessors, building block and algorithm specific. Figure (2.24). Five-tap, low-pass FIR filter .implementation using the coefficients 0.04, 0.12, 0.2, 0.12, and 0.04

.Figure (2.24): FIR filter implementation

:Application Examples of FIR Filters 2.4.2.7

There are many areas where FIR filters have been employed. Including multirate possessing, noise reduction, matched filtering, and image processing. In multirate processing, for example, FIR filters have been successfully used for efficient digital anti-imaging filtering for multirate systems such as high quality data acquisition and the compact disk player. Also there are many other applications for examples music, data transmission, .video, and biomedicine

:Fiber Bragg Grating 2.5

Fiber Bragg grating (FBG) is an all-fiber device which can be used tomake lowcost, low-loss, and compact optical filters and demultiplexers. In an FBG, the Bragg grating is written into the fiber core to create a periodic refractive index perturbation along the axial direction of the fiber, as illustrated in figure (2.25). The periodic grating can be made in various shapes, such as sinusoid, square, or triangle; however, the most important parameters are the grating period L, the length of the grating region L, and the strength of the index perturbation dn. the simplest case, the index profile along the longitudinal direction z, which is most relevant to the performance .[of the fiber grating, is where is the refractive index of the fiber core [2

Figure (2.25): Fiber Bragg grating. L: grating length

Fiber Bragg gratings (FBGs) are effective approaches for addressing optical intensity sensors, because they provide reflective configurations that permit the use of a single fiber lead for both propagating directions of the light. Not only the use of FBG in optical sensor networks provide an effective and compact strategy for exploiting fiber links bidirectionally; actually, the sensitivity of the optical transducer can be enhanced because it is possible to make the optical signal travel through the intensity sensor twice, once for each propagating direction of the light. Finally, FBGs are low-cost and excellent technology to achieve WDM sensors, because they can be used as .spectral splitting devices of broadband light sources

:Lock-in Amplifier 2.6

Lock-in amplifiers are used to detect and measure very small AC signals-all the way down to a few nanovolts. Accurate measurements may be made even when the small signal is obscured by noise sources many .thousands of times larger

Lock-in amplifiers use a technique known as phase-sensitive detection to single out the component of the signal at a specific reference frequency and phase. Noise signals, at frequencies other than the reference frequency, are rejected and do not affect the measurement [14]. Lock-in measurements .require a frequency reference

Typically, an experiment is excited at a fixed frequency (from an oscillator or function generator), and the lock-in detects the response from the experiment .at the reference frequency

:The Typical Lock-In Amplifier 2.6.1

The block diagram of a typical lock-in amplifier is shown in figure (2.26). Readers should be aware that the following discussion makes no assumptions as to the technology used to implement each of the circuit elements and that analog, mixed technology and digital methods that may be .[used [15

Figure (2.26): lock-in amplifier

Chapter Three

Sensor Network Design and Simulation

:Introduction 3.1

Remote addressing of photonic sensors using optical fibers and multiplexing schemes can be easily integrated in wavelength-division multiplexing (WDM) networks and commercial devices and laboratory prototypes are available for the measurement of several parameters such as ultra sonic, temperature, pressure, humidity, corrosion and displacement.

:Description of the Configuration

A CWDM network operating in reflective configuration for multiplexing remote Radio-Frequency (RF) self-referenced fiber-optic .intensity sensors is analyzed and simulated investigated

Figure (3.1): Proposed CWDM network with *N* self-referenced optical fiber sensors

A broadband light source (BLS) is modulated at a single frequency *f*, thus avoiding the flicker noise (1/f) effect in the measurements at the reception stage. After the transmission stage, a broadband circulator is located in order to launch the modulated broadband signal into the remote sensing points. Each remote sensing point consists on a pair of FBGs placed before and after the fiber-optic sensor (FOS) with central wavelengths *Ri* -(reference wavelength) and *Si* -(sensing wavelength), respectively. The broadband optical circulator receives the reflected multiplexed optical signal with the sensor information. The optical signal is demultiplexed by a CWDM device and delivered to an array of *N* photo detectors (PD) and a lock-in amplifier at the reception stage, description and analysis of network for one channel (remote sensor point figure(3.2

Figure (3.2): One channel remote sensing point

Figure (3.3): Filter configuration

The response of the remote sensing configuration and the measurement technique realized for both self-referencing parameters are simultaneously considered for a generic remote sensing channel *i*. The electro-optical topology with electronic delay lines(FIR) proposed for a single generic remote optical sensor *i* is shown in figure (3.3).The digital filter schematic of the complete sensor topology is shown in figure (3.1) Let *i H* be the sensor loss modulation. In the reception stage, electrical phase-shifts () are applied to the RF modulating signal providing a flexible and easy-reconfigurable operation point of the remote intensity sensor. The delay line filters are deployed in the electrical domain but with a coefficient β_i which depends on .the sensor loss modulation H_i in the sensing point

The response of the remote sensing configuration and the measurement technique realized are considered for a generic sensor channel *i* containing .both corresponding wavelengths λ_{Ri}, λ_{Si} and the electrical phase shifts Ω_1, Ω_2

The system output in the time domain, see Fig. 2(3.3), can be expressed .as follows: The system output in the time domain

where m_{Ri} is the RF modulation index, $R(\lambda_{Ri})$ is the reflectivity of the FBG and d d_{Ri} is the photodetector response at the reference wavelength λ_{Ri}

for the generic remote sensing point i, respectively, and m_{si}, $R(\lambda_{si})$ and d_{si} are .the respective similar parameters for the sensor wavelength λ_{si}

This work has been simulated by OptiSystem(version7) the topology design was realized using the Optisystem development environment, in which particular test development environment, in which measurements were carried out as well .Therefore, an individual parts of this topology will be subsequently focus. The main objective of simulation is to find the best configuration of the system that can operate at optimum performance to be .implemented it on the application systems

This will not only save time but also can provide a clear picture (based on eye diagram, then can create performance graph) of the designed .configurations whether or not the design objectives can be achieved

:OptiSystem Simulator 3.2.1

Optisystem is an innovative optical communication system simulation package for the design, testing and optimization of virtually any type of optical link in the physical layer of the broad spectrum of optical networks, from long-haul systems to local area networks (LANs) and metropolitan area networks (MANs). A system level simulator is based on the realistic modelling of fiber optic communication systems, new simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be easily expanded with the addition of user components and seamless .interfaces to a range of widely used tools

:Simulation work 3.2.2

The radio frequency technique of coarse wavelength division multiplexing (CWDM) fiber optic intensity sensors for one channel remote sensor has been simulated fig(3.4) by an optisystem software .This work had been divided into three phases, transmission stage, remote sensing point and reception stage, reception and transmission stages both are located in central .(office(CO

(Fig(3.4): Fiber Optic Sensors Implementation based(CWDM

:Central Office 3.2.2.1

With the proposed topology, the Passive Optical Network(PON) access to the sensors is achieved by means of a central office (CO) where the terminal equipment, both transmission and reception stages, are located. The distribution network consists of a primary fiber cable linking the CO to the .(remote sensing the CO to the remote sensing. Fig (3.5

.

Fig(3.5): Central office layout

:Transmission stage 3.2.2.2

The optical transmitter consists of Continuous Wave (CW) laser with frequency of 193.1 THz and output power of 1 MW which is externally modulated at F = 10KHz in a Mach-Zehnder modulator with 30 dB of .(extinction ratio fig (3.5

Which was employed to launch optical power fig (3.6) into the configuration through an ideal circulator. the out put of Continuous Wave laser source and the modulated optical power of Mach-Zender are obtain in fig(3.7) and fig(3.8) respectively. which was employed to launch an optical power into the configuration through an ideal circulator and reaching remote .sensor point

Fig (3.6): Continuous Wave laser (CW) modulated at 10 kHz Mach –Zender

Fig (3.7) Continuous Wave laser out put

Fig (3.8): Mach-Zender out put

:Remote Sensing Point 3.2.2.3

The light is leaded from central office (CO) to remote sensing point fig (3.9) through fiber link, the remote sensing point contain of an intensity sensor located between two Fiber Bragg Grating (FBG) with different wavelength (λ_R) =1550.3nm and (λ_S) =1552nm. The Fiber Optic Sensor (FOS) had been used in this simulation is an Intensity-based fiber optic sensors rely on signal undergoing some loss. They are made by using an apparatus to convert what is being measured into a force that bends the fiber and causes attenuation of the signal. the mechanism of attenuation can produce a measurand-induced change in the optical intensity propagated by an optical fiber .Two continuous optical waves at a reference wavelength ($_R$) and a sensor wavelength (λ_S) reach the remote sensing point with total average .powers P_{Ri}, P_{Si}, respectively

Fig (3.9): Remote sensing point

Both reflected spectra at the two FBGs do not overlap in wavelength, so that the optical crosstalk can be ignored. The optical power reflected at the reference wavelength PR is used as a reference channel, while the measurand induced attenuation H causes a power variation at the sensor wavelength, which can be read in signal PS. The ratio

$$R = \frac{R_s}{R_R}$$

Can be used as self-referenced measurement parameter, because all the power fluctuations taking place out of the sensing point are identical at both the reference and sensor wavelengths, especially if both wavelengths are close .one to each other

Provided that the reflectivity of the reference and sensor FBGs are RR, RS, :respectively, the self-referencing measurement parameter yields

$$R = \frac{R_{si}}{R_{Ri}} \frac{R_s}{R_R} T^2 H^2$$

Where T is the transmission coefficient, taking into account the loss induced at R_S due to the insertion loss in the reference FBG

Figure (3.10): Sensor information wavelength (λ_S) output

Figure (3.11): Sensor information wavelength (λ_S) output in time domain

Figure (3.12): Reference wavelength (λ_R) out put

Figure (3.13): Reference wavelength (λ_R) out put in time domain

:Reception stage 3.2.2.4

An ideal circulator receives the reflected an optical signal with sensor information to Coarse Wavelength Division Multiplexing which it demultiplexing by (CWDM) and collected by photo-detectors and phase- .shifted by the electronic delay filters at the reception stage

.Figure (3.15) show the output of electronic delay filter

A lock-in amplifier was used in this stage in order to obtain both self- .(referencing parameters show in figure (3.13

Figure (3.16) shows the subsystem of A lock-in amplifier and whose (the both self-referencing permeates (R, ø) in figure (3.17

Fig (3.14): reception stage layout

Figure (3.15) output of electronic delay filter

Fig (3.16): lock –in amplifier subsystem lay out

(Figure (3.17): Two self-reference parameters output(R, ø

:FIR filter and fiber delay coil compare 3.2.3

In the intensity-based optical sensors the main drawback is the interference from variation in losses non-correlated to the sensor modulation, so some strategy must be integrated in the sensor network or, recently, even integrated in the remote sensing point to overcome those undesirable power fluctuations Different configurations providing self-referencing techniques to solve this disadvantage have been reported employing all-optical layouts in the sensor-head with interferometric schemes such as Michelson or Sagnac, .(ring resonators schemes or non compact fiber delay coils figure (3.18

(Figure (3.18):Schematic of CWDM self-referenced sensors using fiber delay coil(L

Identical fiber coils of 450m are emplaced at each sensing point[13]. These fiber delay coils at all sensing points must be identical in order to share the two modulation frequencies at the transmission stage for all the sensors; otherwise the operation point of the measurement technique would be different for each sensor, which is not a desirable situation. A maximum distance of 25 km between the CO and the remote sensing is estimated for a total emitted optical power of 84 mW in the *C-L* band. For a fixed phase-shift value , there is a strong tradeoff between the length L of the delay fiber and the modulation frequency f. This is caused because, in these all-optical approaches, the propagation time of light along the delay fiber is used to achieve a phase-shift between the radio-frequency (RF) electrical beating signals in the photo-detector. This tradeoff represents the main drawback of all-optical approaches for self-referencing intensity sensors. For a fixed phase-shift value , the relation between modulation frequency and the length .(of a fiber delay coil is shown in table(3.1

Table (3.1): Tradeoff between modulation frequency(f) and length of delay (fiber (L

(Modulation frequency(f	(Length of delay fiber(L
kHz 100	m 287
kHz 50	m 574
kHz 25	km 1.15

but in the proposed fiber-optic intensity sensor emplaced with in two Fiber Bragg Gratings (FBG) and FIR filter in the reception stage is shown in figure(3.1)it is needed only one modulation frequency whose value can be chosen depending on the application. The self-referencing parameters defined for this electro-optical topology depend only on the phase-shifts selected at the reception stage. The behavior of the self-referencing parameters versus sensor losses modulation at the sensing points depends only on the electrical phase-shifts configured at the reception stage. the behavior of the self-referencing technique can be modified in a single point and in an easy and flexible way just by changing the electrical phase-shifts (in the electrical domain) at the reception stage. Furthermore, the optical power modulation of the sensor at the remote sensing point can be related to the coefficients of the filter structure thus encoding the filter response either magnitude or in phase .and performing self-referenced measurements

Chapter Four

Conclusions and Recommendation

:Conclusions 4.1

In this thesis, a novel self-referenced radio-frequency -based CWDM fiber-optic intensity sensor network with a reflective star topology for multiplexing and interrogation of *N* remote sensing points is proposed and had been simulated by optisystem software version7 RF modulation permits to avoid the effect of the flicker noise (1/f) at the reception stage. By including two delay lines at the reception stage implemented in the electrical domain instead of using FIR electrical filter , arbitrary modulation frequencies can be set and phase shift reconfiguration can overcome tolerance errors .permitting an easy-reconfigurable

:Recommendation 4.2

Coarse WDM (CWDM) allows low-cost WDM to be deployed (as device cooling is not required); CWDM uses channel spacing of 20 nm, so only eight or so channels can normally be deployed. OCDMA as a robust complementary technology that could also be deployed in conjunction with CWDM to increase the number of users. As with WDM, OCDMA offers the possibility of translation from one channel to another (code translation), opening many interesting possibilities. or employing devices such as arrayed-waveguide gratings (AWG) for dense WDM (DWDM) instead of CWDM .devices if required

References

.Jim, H., 2003.Fiber optics technician's manual.2nd edition .1

Rongqing,H.and Maurice, O., 2009.Fiber optic measurement .2
.techniques. San Diego : Elsevier Inc

Gerd,K.,ed.,1993.Optical fiber communications.2nd edition. New .3
.Uork: Mc Graw-Hill, Inc

Duwayne, R., Anderson., Larry, J., and, Florian, .4
G.2004.Troubleshooting optical fiber network.2nd edition. San
.Diego: Elsevier, Inc

Chinlon, L.,ed.,2006.Broadband optical access networks and fiber- .5
.to-the home.Southern Gate: John Wiley & Sons, Ltd

Fedor, M., ed., 2009.Fiber optics physics and technology. New .6
.York: Springer Heidelberg

Tarmo, A., 2003.Telecommunications network engineering.2nd .7
.edition. London: Artech House

.J.P.L.,1993. Wavelength Division Multiplexing.Paris:Masson .8

Fiberdyne Labs, Inc.,2003.<http:// www.fiberdyne.com>[accessed .9
.[at 5.2.2010

Word academey of siennce, engineering, and .10
.(technology(Anon.,2008

Richard,G.L., 2004, Understanding digital signal processing. 2nd .11
.edition. Printed Hall PTR

Steven, W.S., The scientist and engineer's guide to digital signal .12
.processing

J. Montalvo, O. Frazao, J. L. Santos, C. Vázquez, and J. M. .13
Baptista, (2009) “Radio-frequency self-referencing technique with

enhanced sensitivity for coarse WDM fiber optic intensity
. sensors," J. Lightwave Technol. 27(5), 475–482

.14 About lock-in amplifier, http://www.think.SRS.com [[accessed at
.[15.7.2011

.15 Lock-in amplifier <http://www.signal recovery.com>[accessed at
.[3.6.2012

Table of Contents

Appendices