



Simulações Utilizando o OptiSystem



Belém - Mar 2006



Conteúdo

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2. O Ambiente de Simulação
 - 2.1 Conceito de SubSistema
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8. Exemplos: Sistemas WDM, SCM
9. Comentários Finais

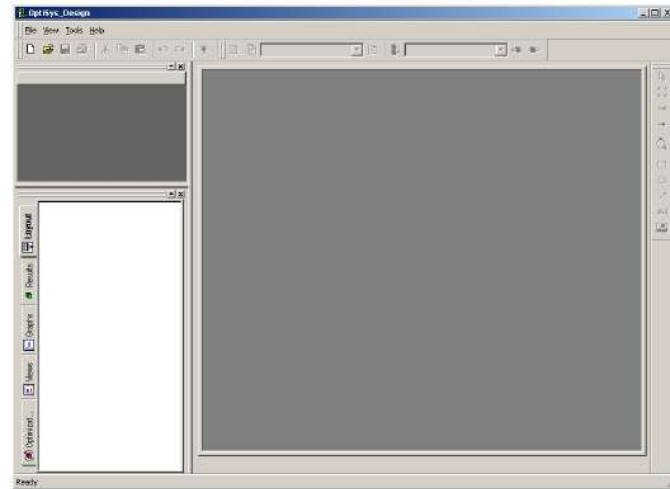
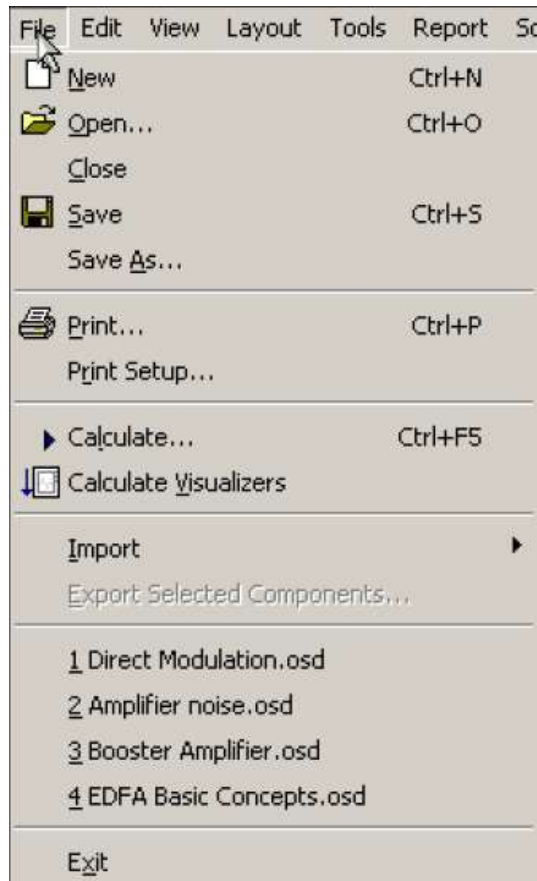


1. Visão Geral

- Ferramenta de projeto de sistemas a fibra óptica
- Aplicações: FTTH, projeto CATV, PON, anéis SONET/SDH, amplificadores ópticos, WDM ou TDM, SCM
- Biblioteca de componentes, todos como um único *package*
- Componentes e visualizadores: Ópticos e Elétricos
- Modelos: dinâmicos e estacionários
- Domínio da frequência (λ) e do tempo
- Cosimulação: MatLab, EDA (ex. Spice), software Optiwave
- Estimativa de custo relativo ao layout simulado
- Requer chave de hardware para funcionar
- 1 ano de assistência e acesso a versões atualizadas



2. O Ambiente de Simulação



- *Project Overview*
- Biblioteca de Componentes
- *Project Browser*
- *Parameter Groups*
- Janela Mostrando Evolução dos Cálculos

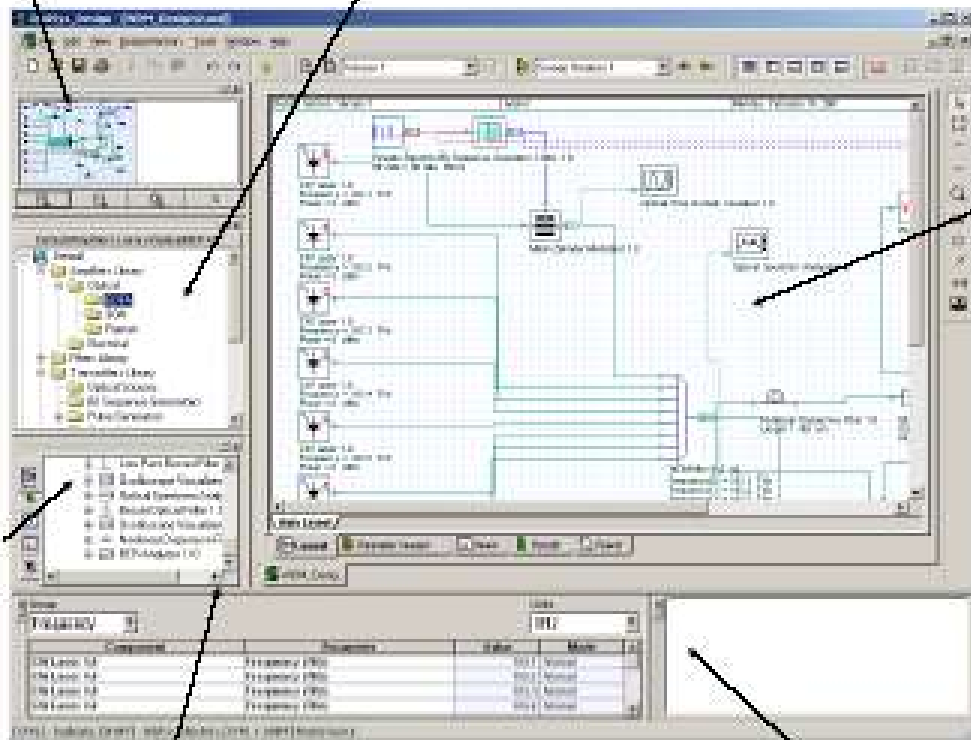


Área de Trabalho

*Múltiplos layouts
Linguagem Script*

Project Overview

Component Library



Layout Editor

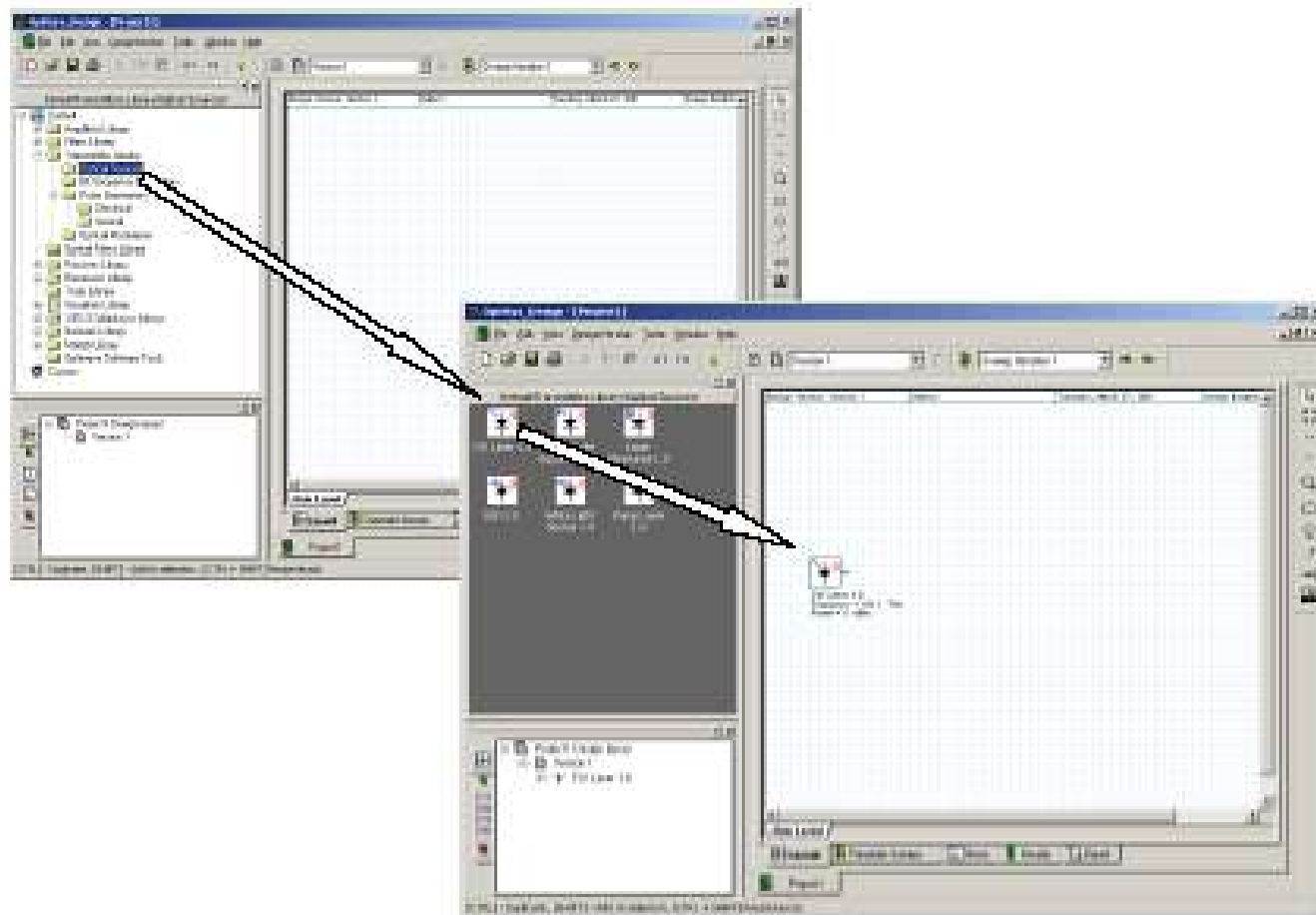
Project Browser

Parameter Groups

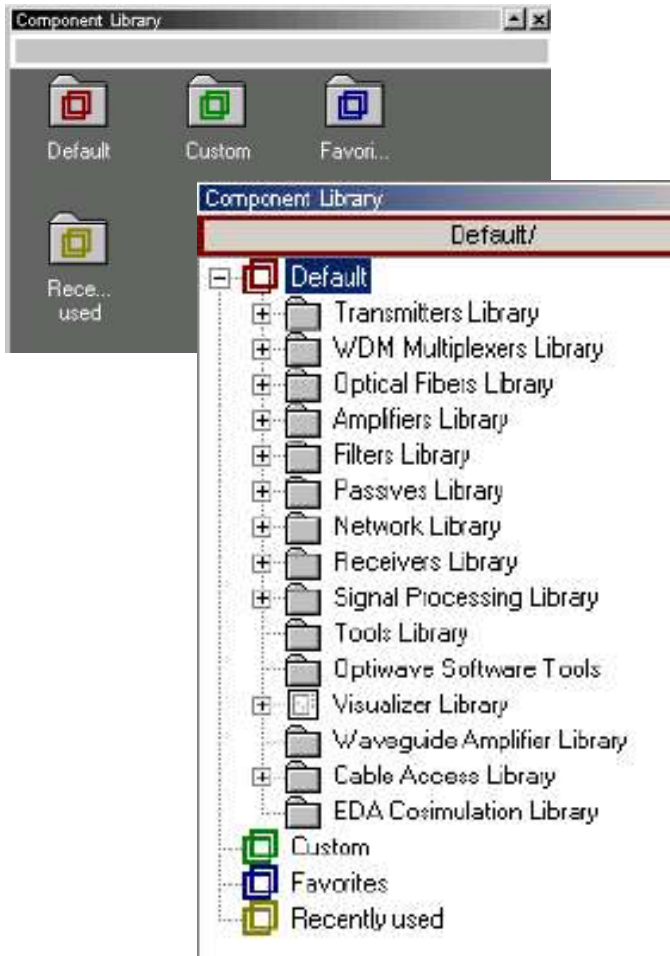
Output Window



Selecionando Componentes na Biblioteca



Elementos Presentes no Layout

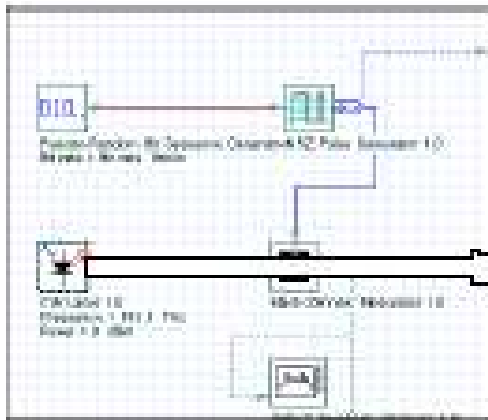


The Project Browser window shows a table of project elements. The table has two columns: 'Name' and 'Value'.

Name	Value
Version 1	10
CW Laser 1.0	CW Laser 1.0
Parts	
Output	Optical Signal
Parameters	
Low Pass Bessel Filter 1.0	Low Pass Bessel Filter 1.0
Mach-Zehnder Modulator...	Mach-Zehnder Modulator 1.0
NRZ Pulse Generator 1.0	NRZ Pulse Generator 1.0
Optical Attenuator 1.0	Optical Attenuator 1.0
Optical Spectrum Analyze...	Optical Spectrum Analyzer 1.0
Optical Time Domain Visu...	Optical Time Domain Visualizer 1.0
Oscilloscope Visualizer 1.0	Oscilloscope Visualizer 1.0
Photodetector PIN 1.0	Photodetector PIN 1.0
Pseudo-Random Bit Seq...	Pseudo-Random Bit Sequence Generator 1.0



Parâmetros de Entrada dos Componentes



Label: CW Laser 1.0 Gain: 0.00

Main Parameters Statistics Help Help/Context

Prop	Name	Value	Units	Default
<input checked="" type="checkbox"/>	Frequency	192	THz	192THz
<input checked="" type="checkbox"/>	Power	0.0000	dBm	0dBm
<input type="checkbox"/>	Linewidth	100MHz	Hz	100MHz
<input type="checkbox"/>	Initial phase	0.0000	rad	0.0000

Legend

System

Reset Only

Help

CW Laser 1.0
Frequency = 192 THz
Power = 0 dBm

Prop	Name
<input checked="" type="checkbox"/>	Frequency
<input checked="" type="checkbox"/>	Power
<input type="checkbox"/>	Linewidth
<input type="checkbox"/>	Initial phase



Facilidades Adicionais Sobre os Componentes

Label: CW Laser 1.0 Cost: 0.00

Disp	Name	Value	Units	Mark
<input checked="" type="checkbox"/>	Frequency	150.1	Hz	Normal
<input checked="" type="checkbox"/>	Power	0	dBm	Normal
<input type="checkbox"/>	Linewidth	0	Hz	Normal
<input type="checkbox"/>	Initial phase	0	rad	Normal

Label: CW Laser 1.0 Cost: 0.00

Disp	Name	Value	Units	Mark
<input checked="" type="checkbox"/>	Frequency	150.1	Hz	Normal
<input checked="" type="checkbox"/>	Power	0	dBm	Normal
<input type="checkbox"/>	Linewidth	0	Hz	Normal
<input type="checkbox"/>	Initial phase	0	rad	Normal

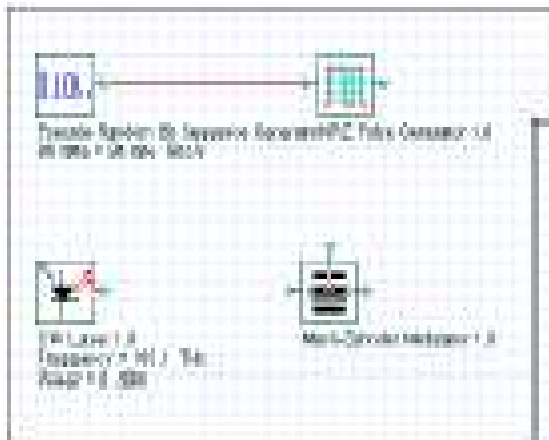
Frequency Units

Power Units

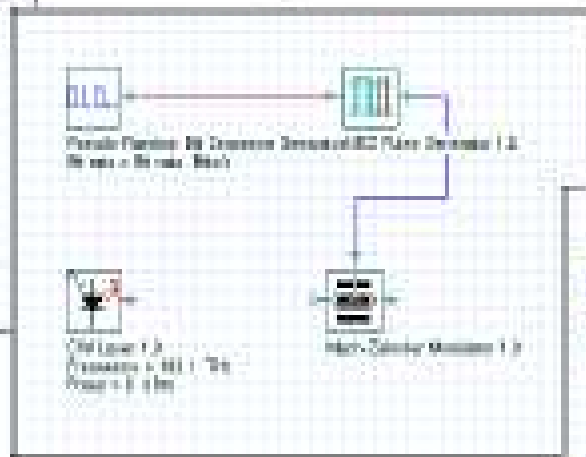


Como Montar um Transmissor

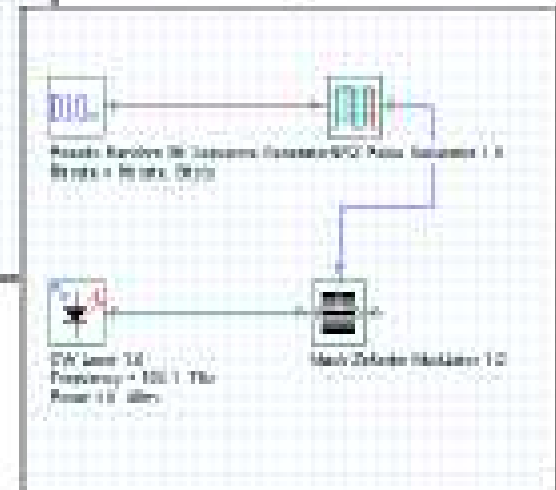
1



2



3

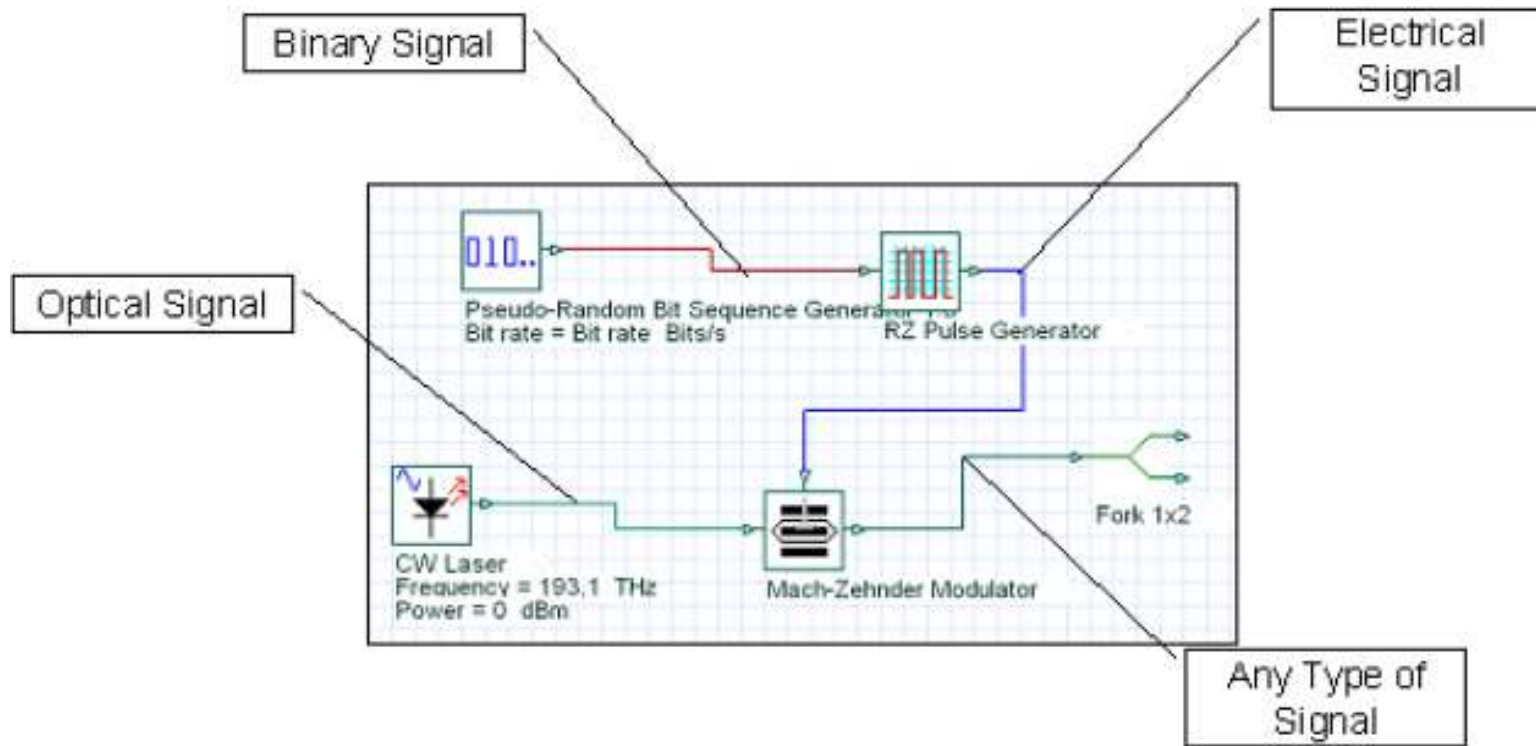


Conexão entre componentes





Tipos de Sinais e Conexões





Prática 1

- 1a. Montar um transmissor óptico (1556 nm) e rodar!
- 1b. Visualizar resultados (OSA, Osciloscópio, !

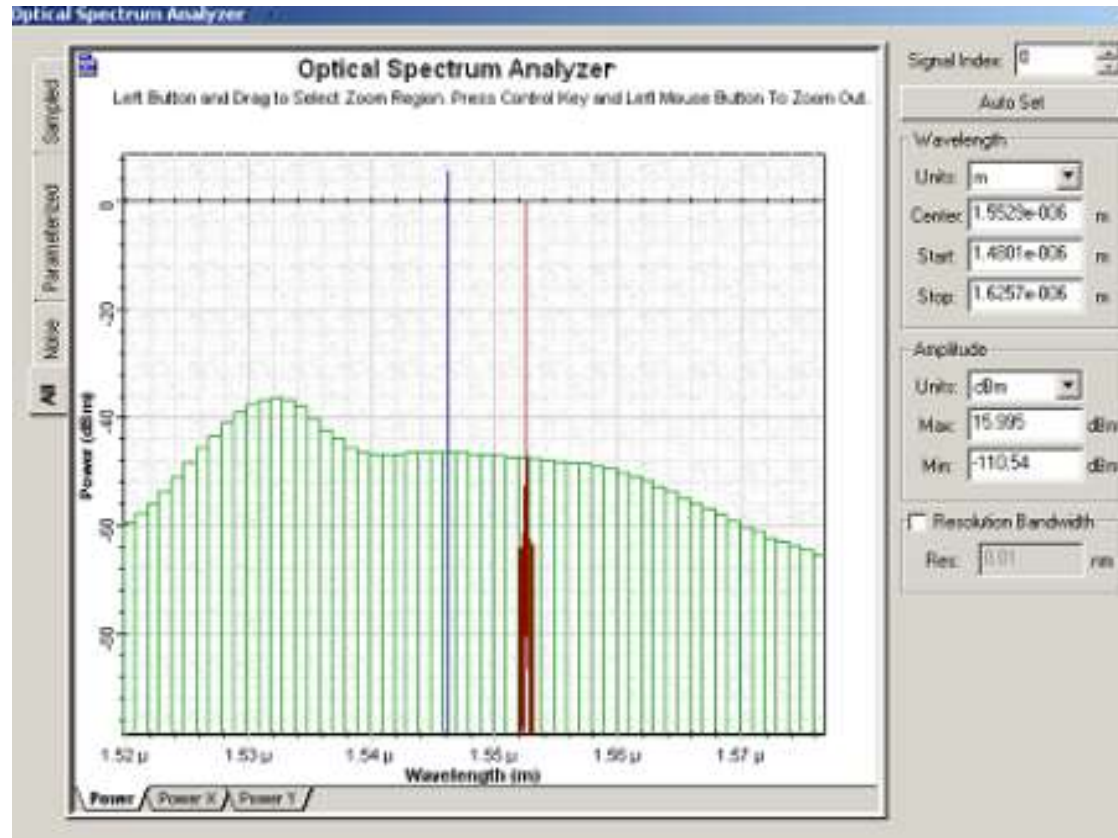


Representação do Sinal Óptico

Sinais Amostrados

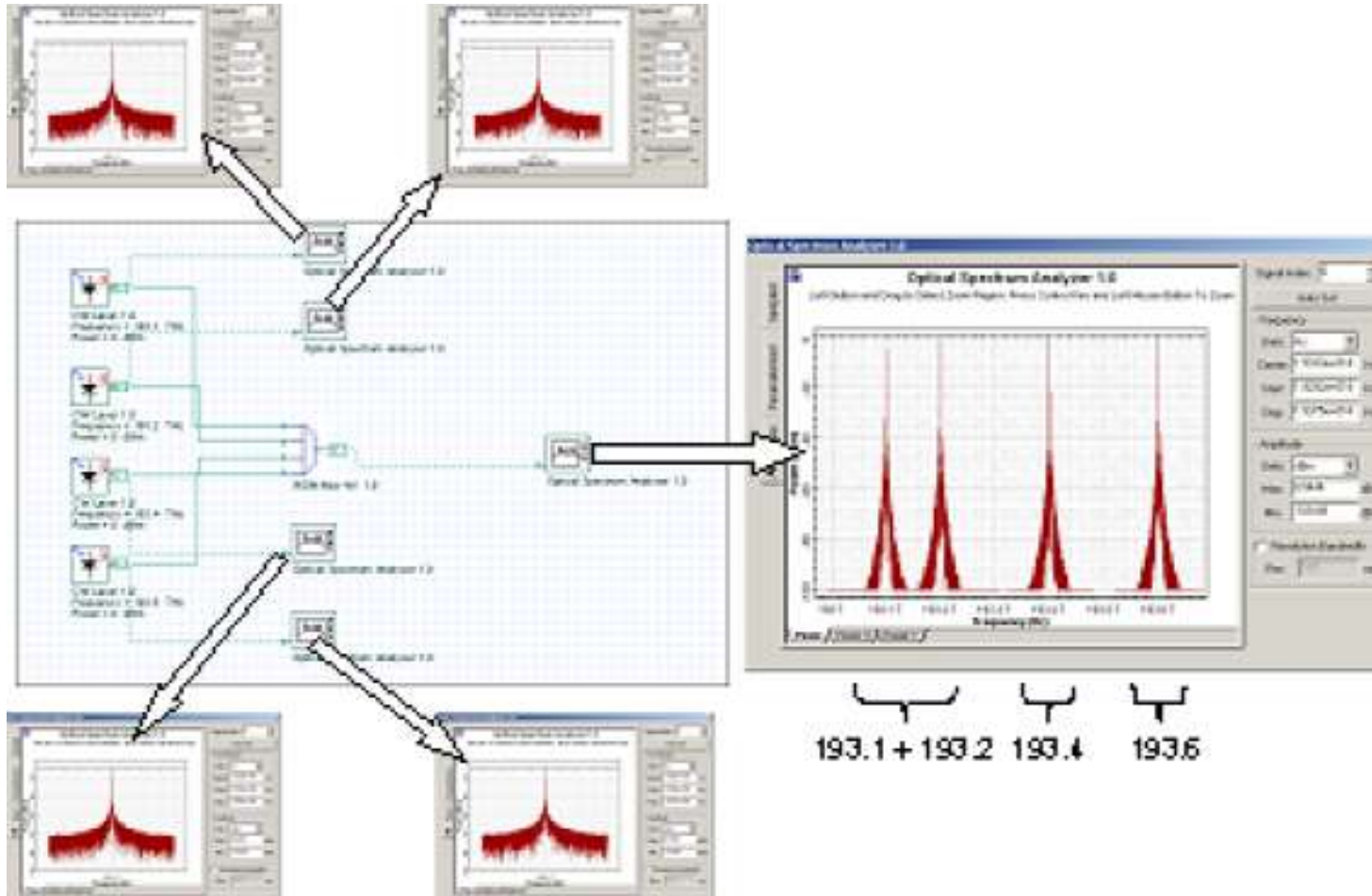
Sinais Parametrizados

Noise Bins



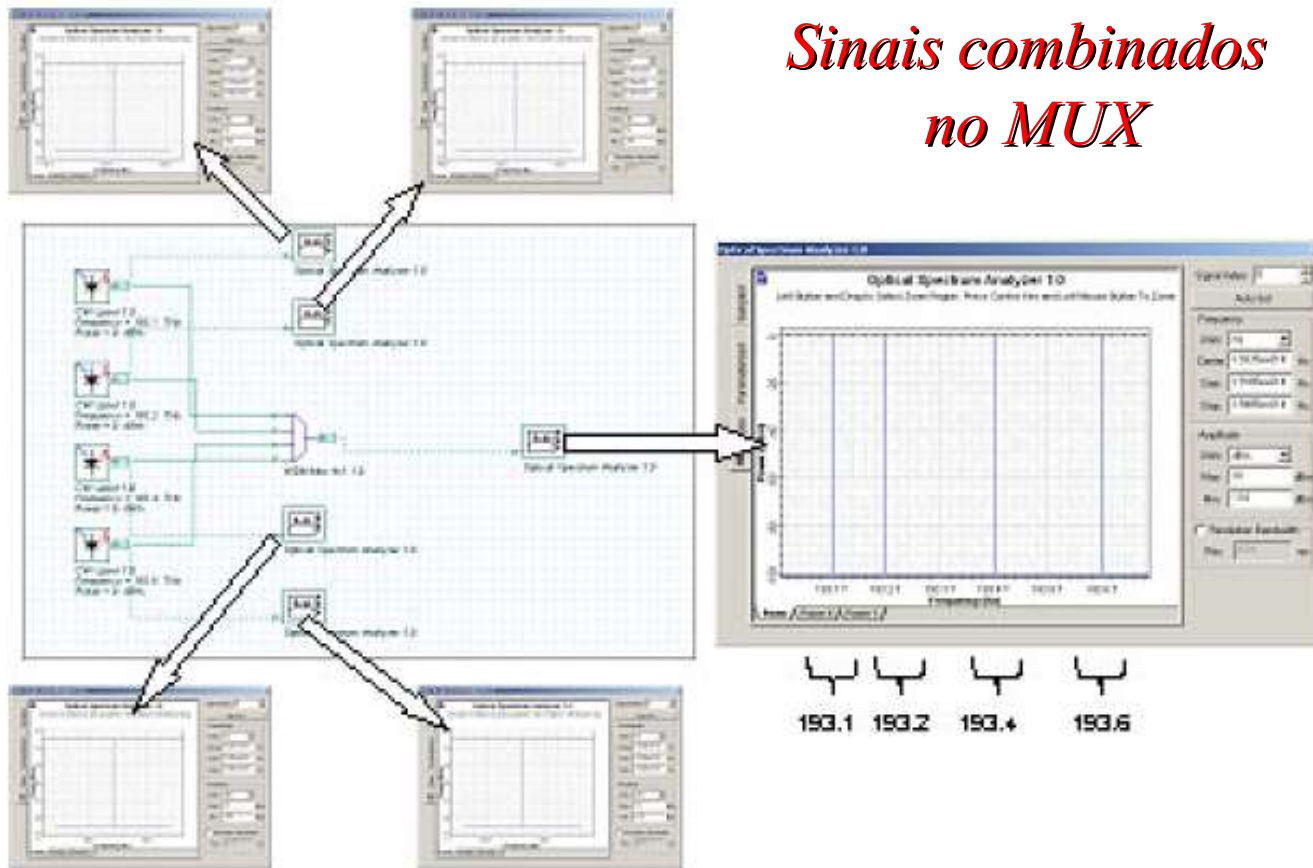


Sinais Amostrados





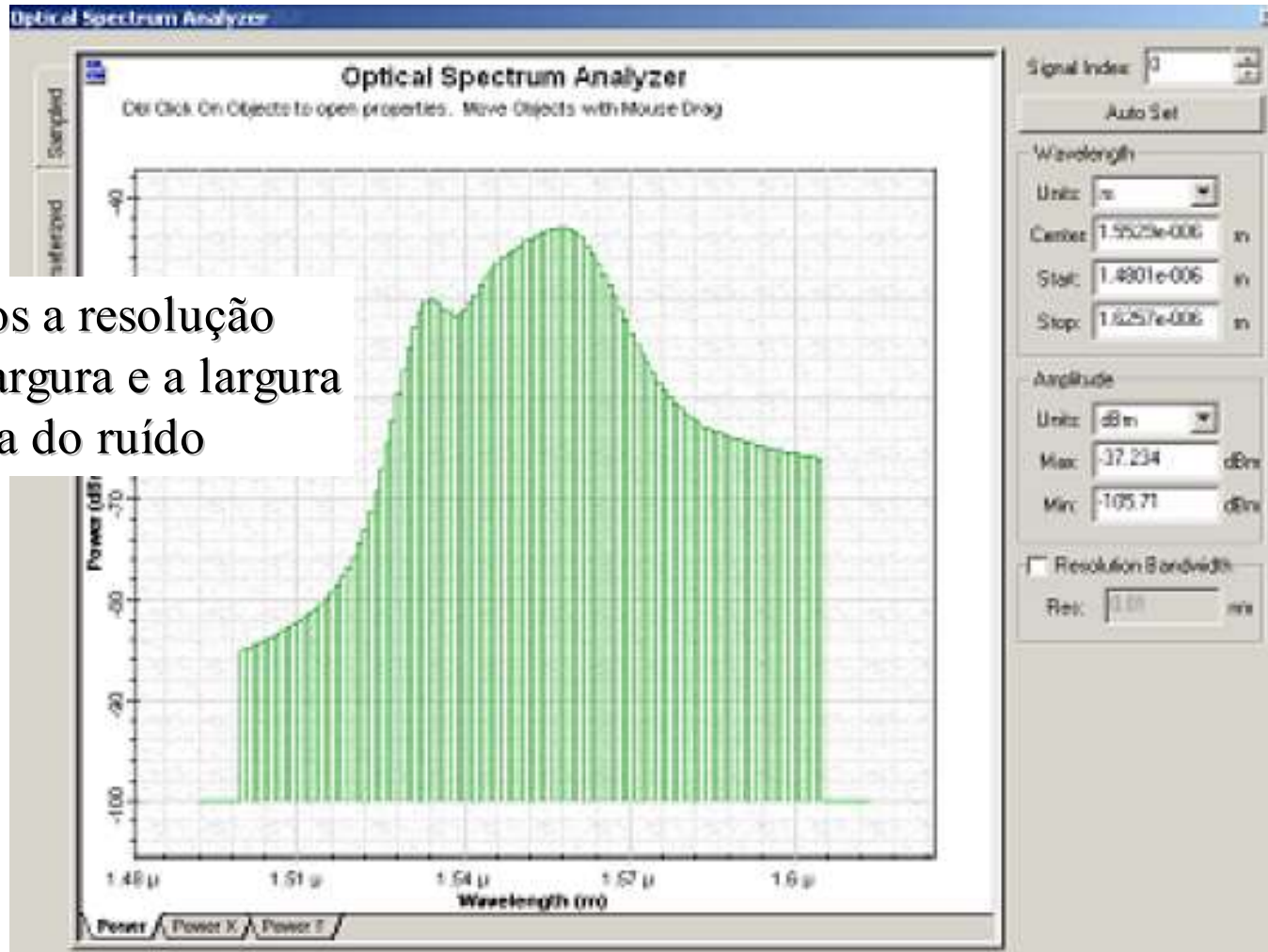
Sinais Parametrizados





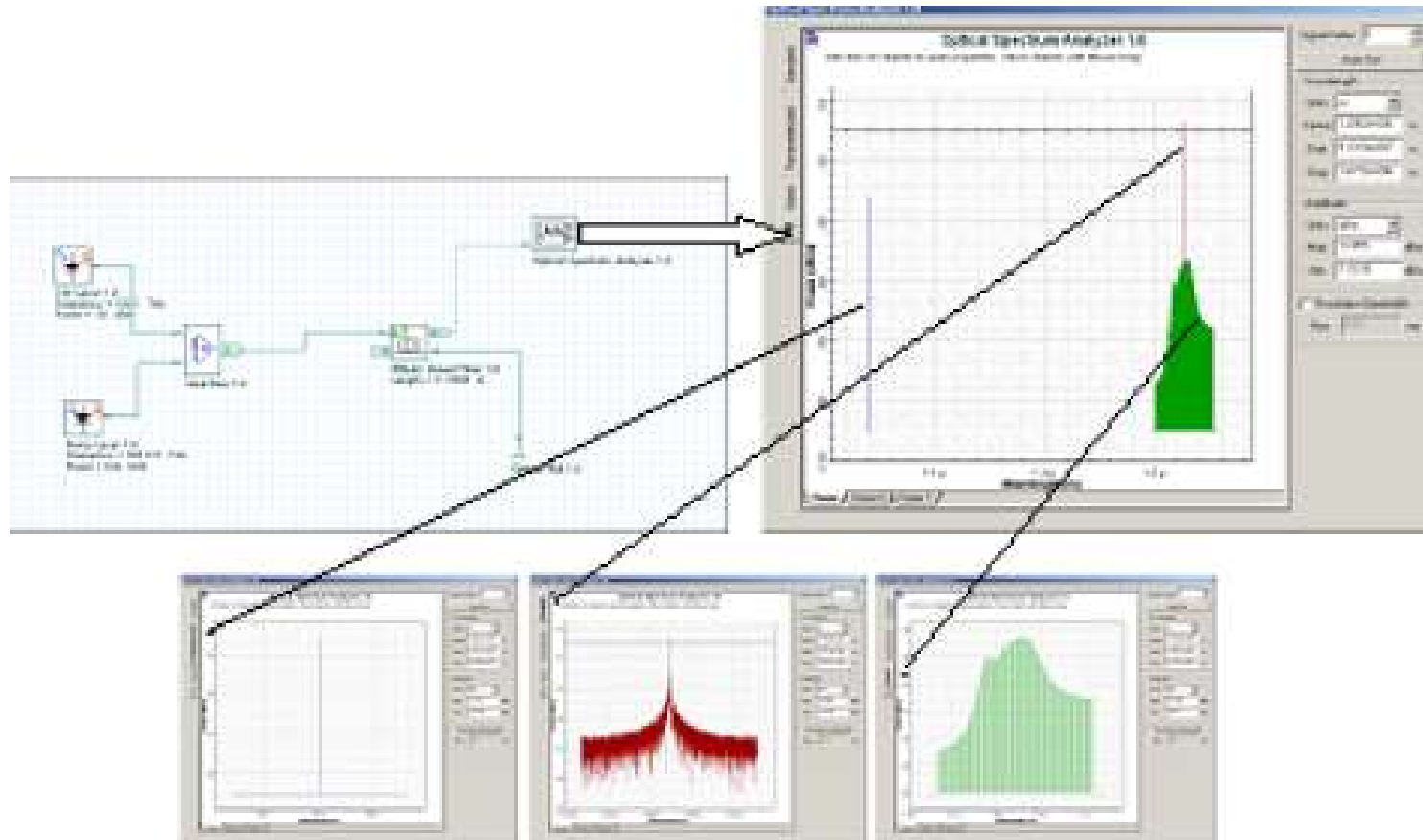
Noise Bins

Definidos a resolução
inicial largura e a largura
de banda do ruído



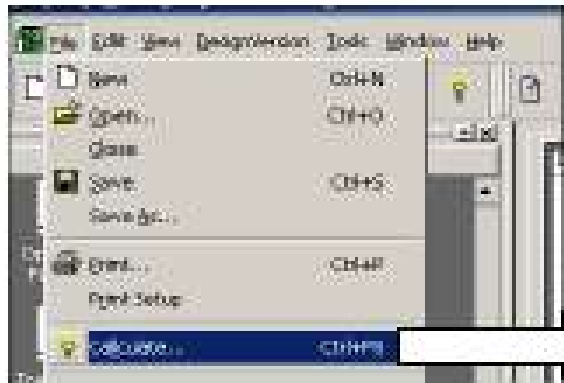


Sinais Combinados no EDFA

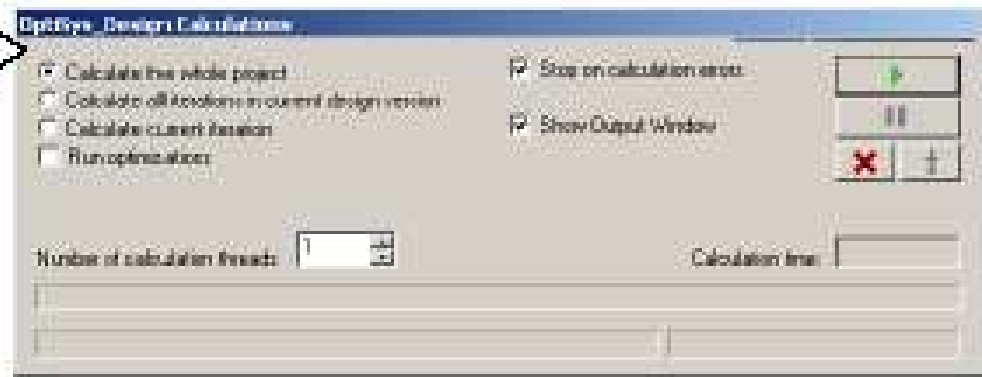




Rodando as Simulações

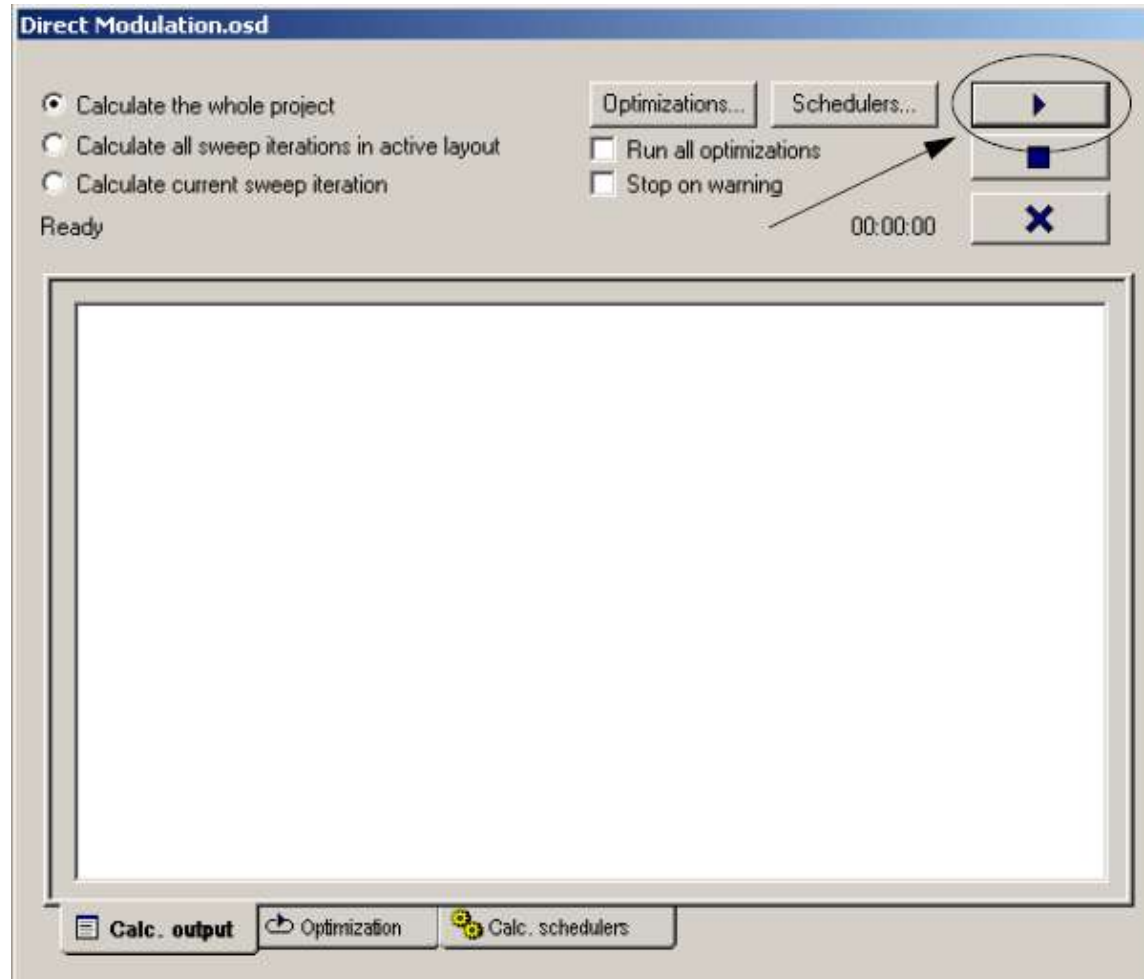


Report mostrando a evolução dos cálculos





Acompanhando a Evolução dos Cálculos





Acompanhando a Evolução dos Cálculos

BER InputPowerSweep.osd

Calculate the whole project
 Calculate all sweep iterations in active layout

Optimizations... Schedulers... [Pause] [Stop] [Close]

Run all optimizations
 Stop on warning

Calculation progress: Calculating Project: BER InputPowerSweep.osd, Layout: Version 1, Sweep 1 of 10 00:00:22

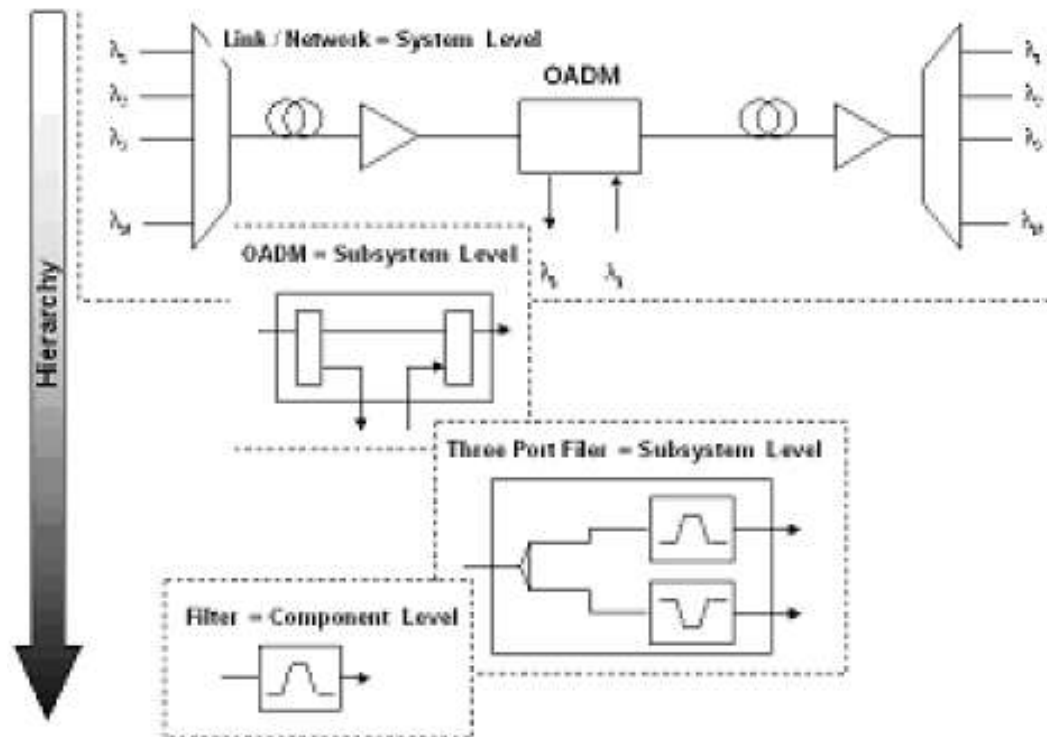
Parameter:		Result:	
Parameter	Value	Result	Value
CW Laser 1.0-Random seed in...	0	BER Analyzer 1.0-Max. Eye Openin...	100
CW Laser 1.0-Generate random...	0	BER Analyzer 1.0-Bit Rate (Bits/s)	1e+010
CW Laser 1.0-Frequency	193.1	BER Analyzer 1.0-Min. BER	1
NRZ Pulse Generator 1.0-Ampli...	1	BER Analyzer 1.0-Min. BER after F...	1
Optical Attenuator 1.0-Attenuati...	30.3	BER Analyzer 1.0-Min. log of BER	0
Oscilloscope Visualizer 1.0-Gen...	0	BER Analyzer 1.0-Noise Power (dBm)	-136.505
Oscilloscope Visualizer 1.0-Ran...	0	BER Analyzer 1.0-Max. Eye Height ...	0
Optical Time Domain Visualizer ...	0	BER Analyzer 1.0-Max. Eye Openin...	100
Optical Time Domain Visualizer ...	0	BER Analyzer 1.0-Bit Rate (Bits/s)	1e+010
CW Laser 1.0-Random seed in...	0	BER Analyzer 1.0-Min. BER	1
CW Laser 1.0-Generate random...	0	BER Analyzer 1.0-Min. BER after F...	1
CW Laser 1.0-Frequency	193.1	BER Analyzer 1.0-Min. log of BER	0
NRZ Pulse Generator 1.0-Ampli...	1	BER Analyzer 1.0-Noise Power (dBm)	-136.505
Optical Attenuator 1.0-Attenuati...	30	BER Analyzer 1.0-Max. Eye Height ...	0
Oscilloscope Visualizer 1.0-Gen...	0	BER Analyzer 1.0-Max. Eye Openin...	100
Oscilloscope Visualizer 1.0-Ran...	0	BER Analyzer 1.0-Bit Rate (Bits/s)	1e+010

Calc. output Optimization Calc. schedulers



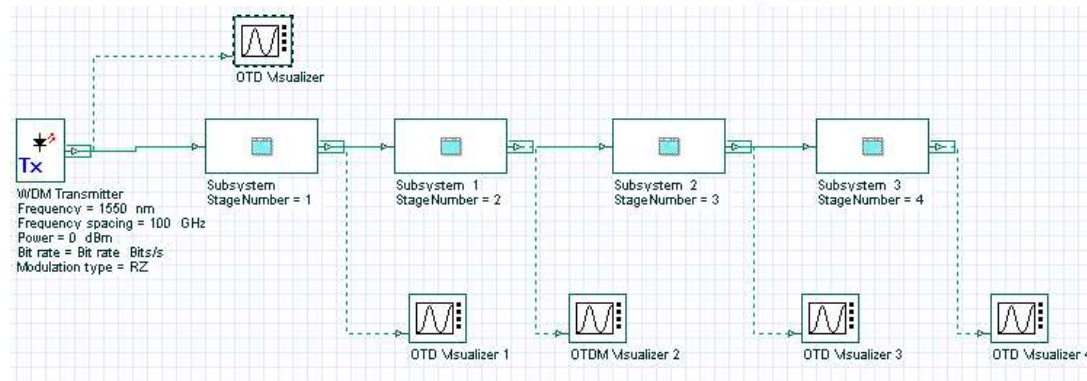
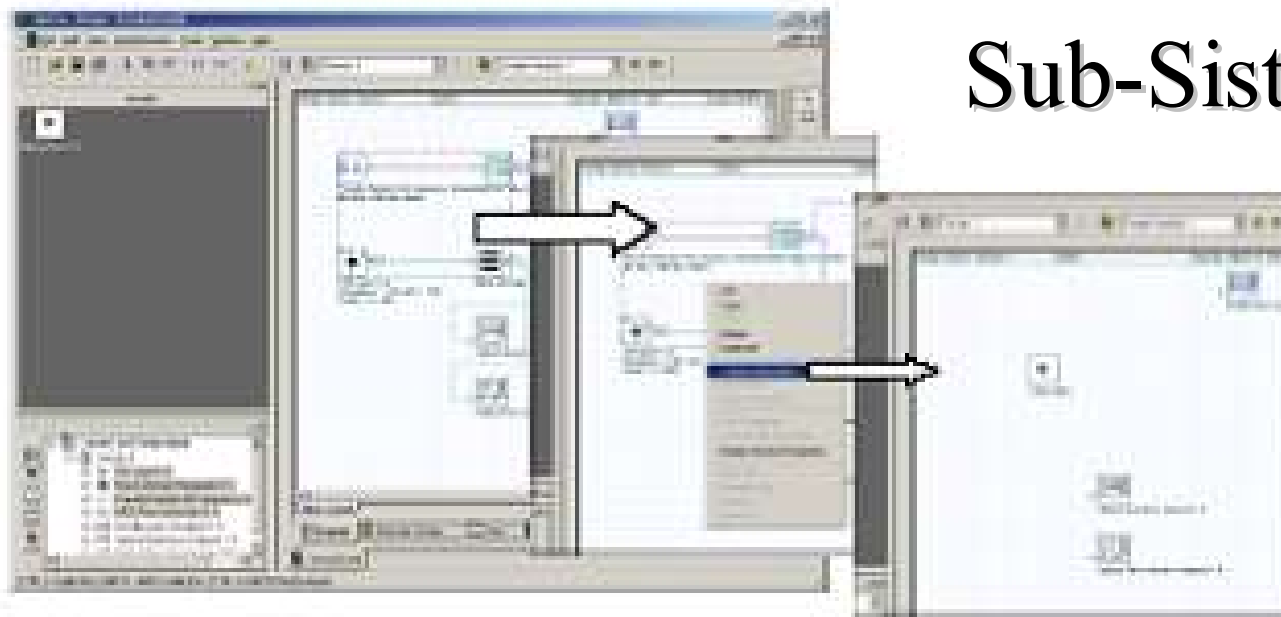
2.1 Conceito de Sub-Sistema

Permite montar o seu próprio componente





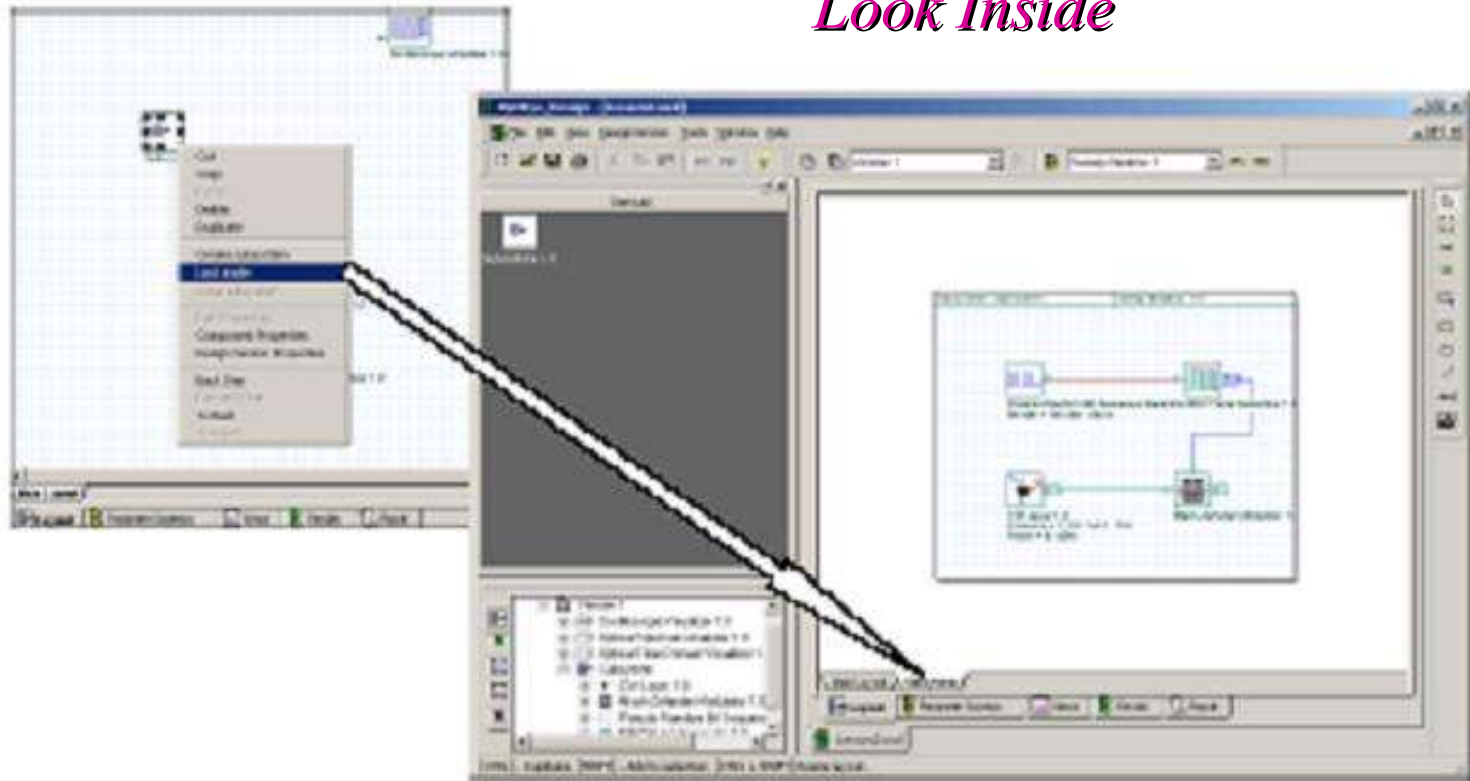
Criando um Sub-Sistema





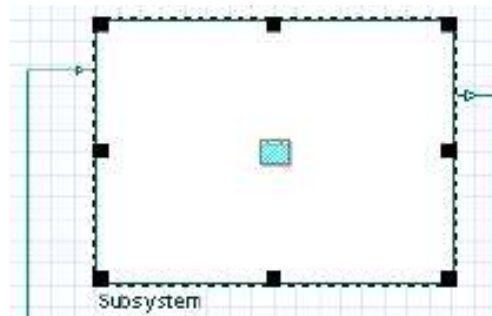
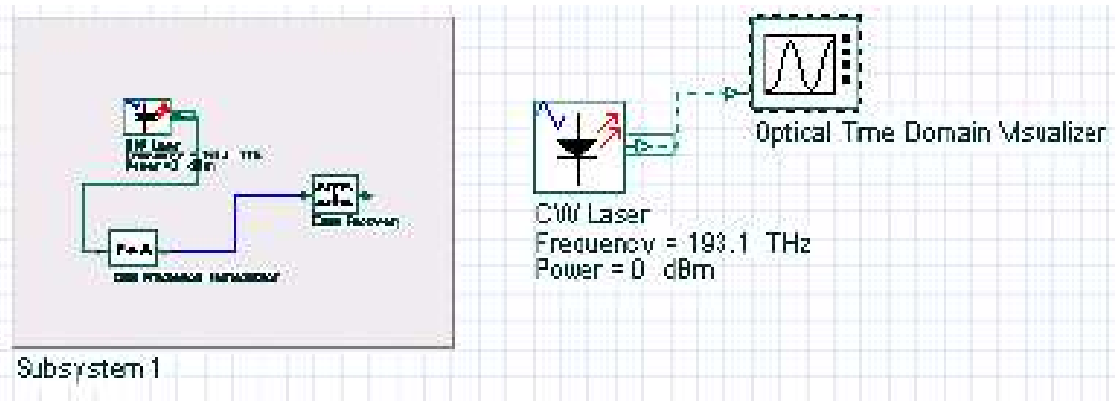
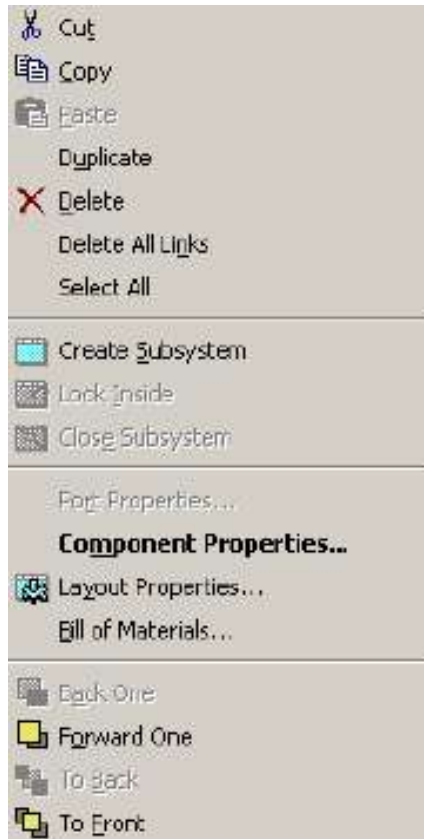
Entrando e Saindo do Sub-Sistema

Look Inside



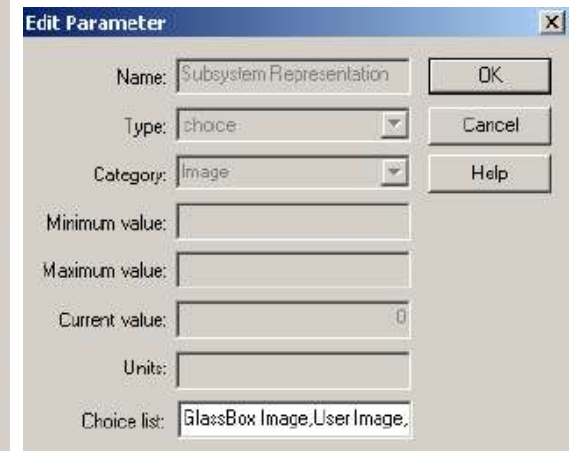
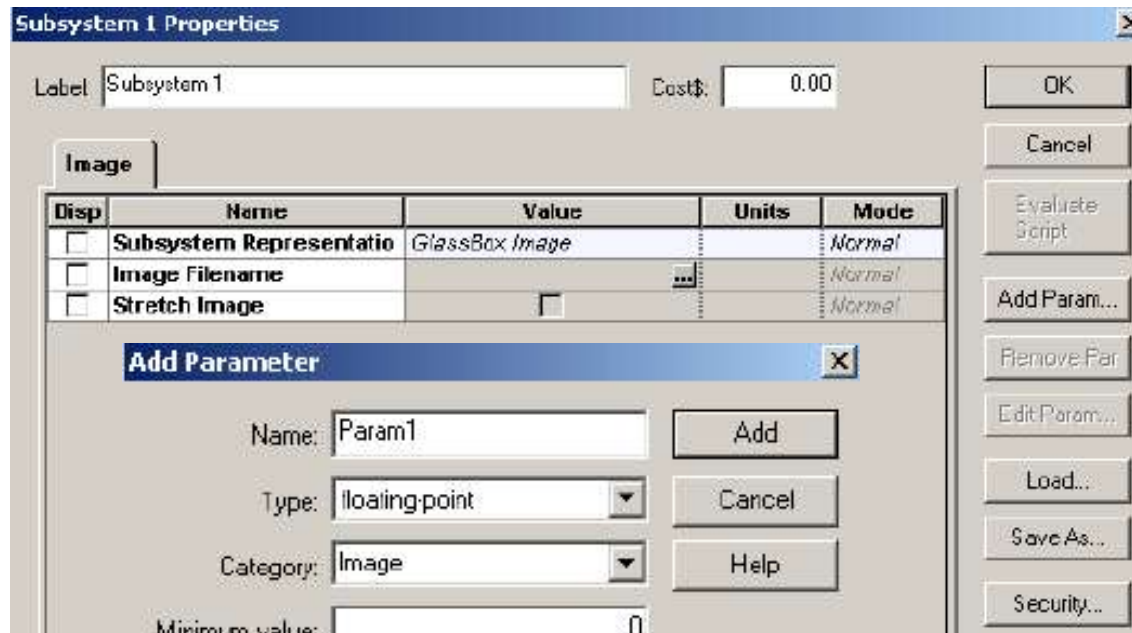


Trabalhando com Sub- Sistemas



*Agrupar componentes
e simplificar o layout*

Alterações no Sub-Sistema





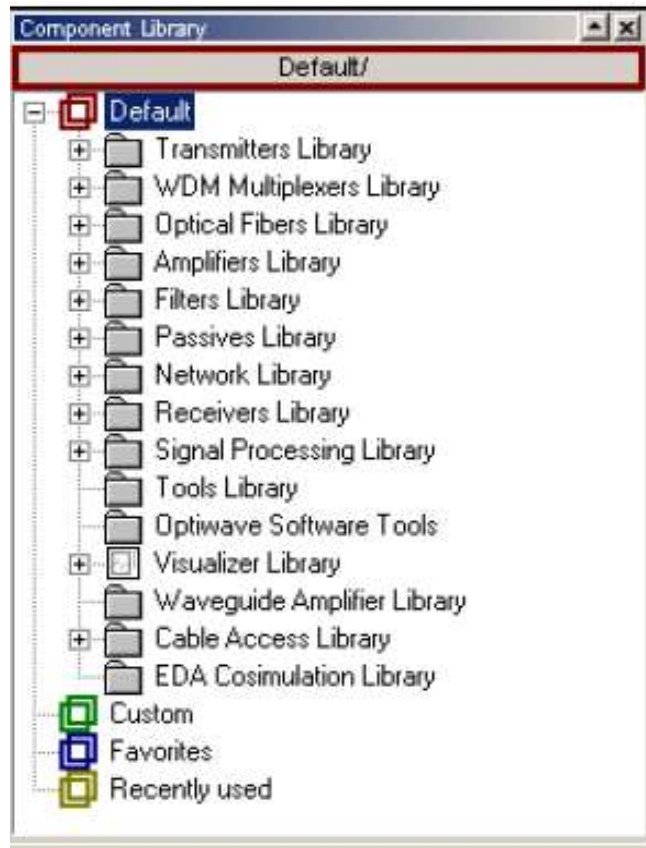
Prática 2

2a. Carregar exemplo “Lesson1.osd”

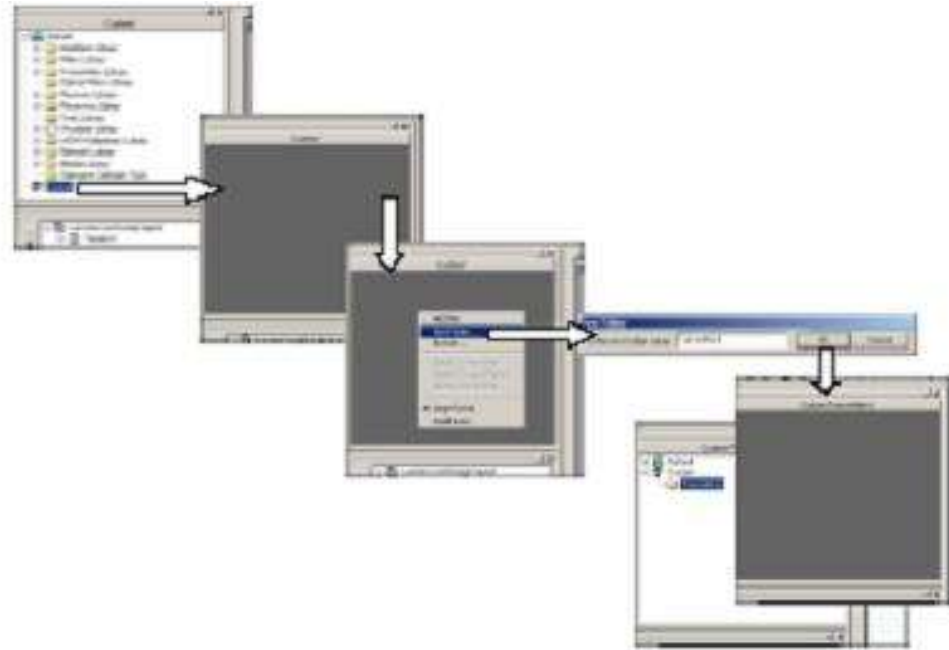
2b. Converter o TX em um sub-sistema



3. Biblioteca de Componentes



Criando pastas na biblioteca de componentes de interesse





Parâmetros Globais

Bit rate = 2,5 Gb/s

Sequence Length = 128 bits

Time Window = 5,12e-08

Version 1 Parameters

Label:

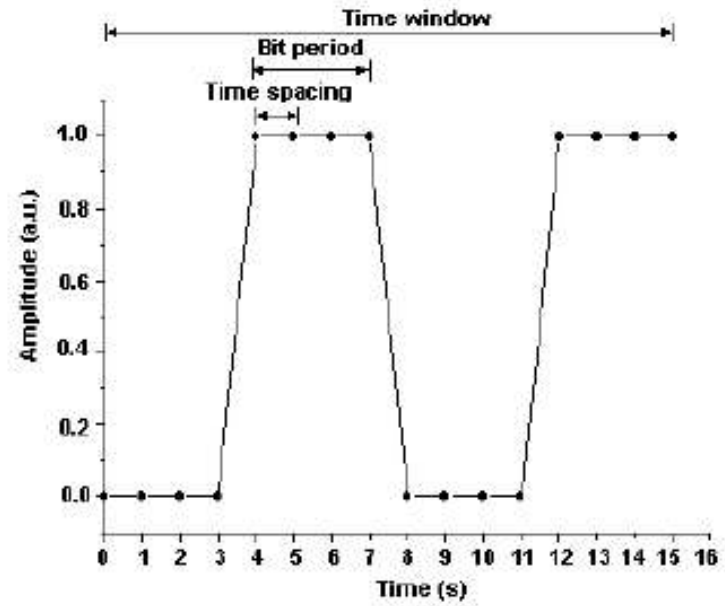
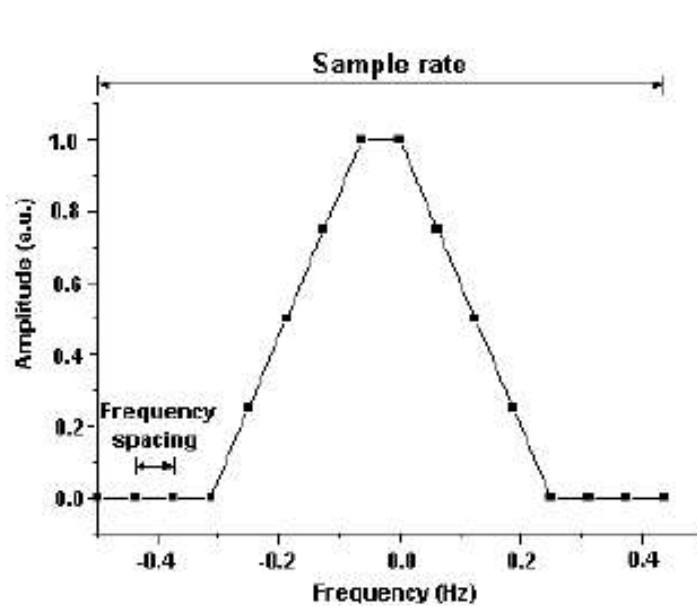
Simulation | Signals | Noise | Signal tracing

Name	Value	Units	Mode
Simulation window	Set bit rate		Normal
Reference bit rate	Set bit rate		Normal
Bit rate	Set time window	Bits/s	Normal
Time window	Set sample rate	s	Normal
Sample rate	1280000000000	Hz	Normal
Sequence length	256	Bits	Normal
Samples per bit	128		Normal
Number of samples	32768		Normal
Iterations	1		Normal

OK
Cancel
Add Param...
Remove Par...
Edit Param...



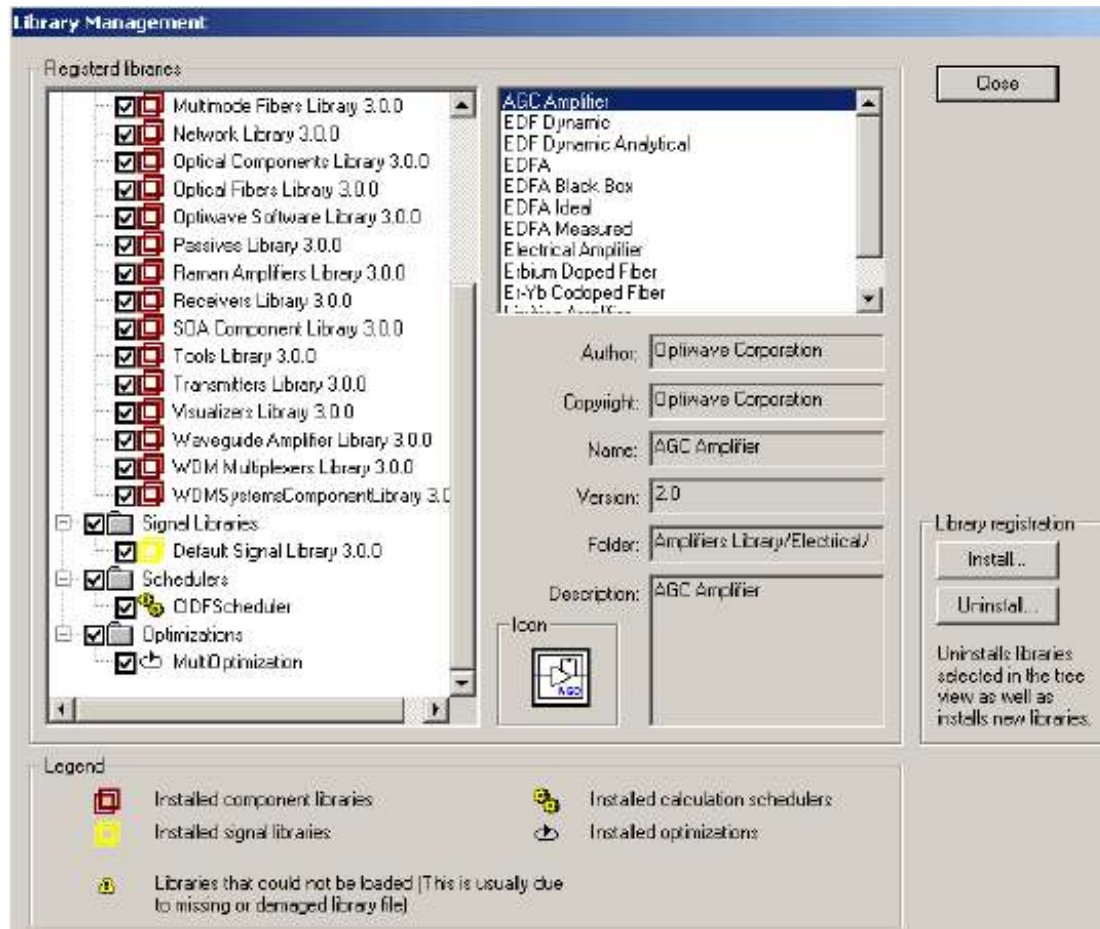
Relação Entre Parâmetros Globais



$\text{Time spacing} = 1 / \text{Sample rate} = \text{Time window} / \text{Number of samples}$
 $\text{Frequency spacing} = 1 / \text{Time window} = \text{Sample rate} / \text{Number of samples}$

$\text{Time window} = \text{Sequence length} \cdot \text{Bit period} = \text{Sequence length} / \text{Bit rate}$
 $\text{Number of samples} = \text{Sequence length} \cdot \text{Samples per bit} = \text{Time window} \cdot \text{Sample rate}$

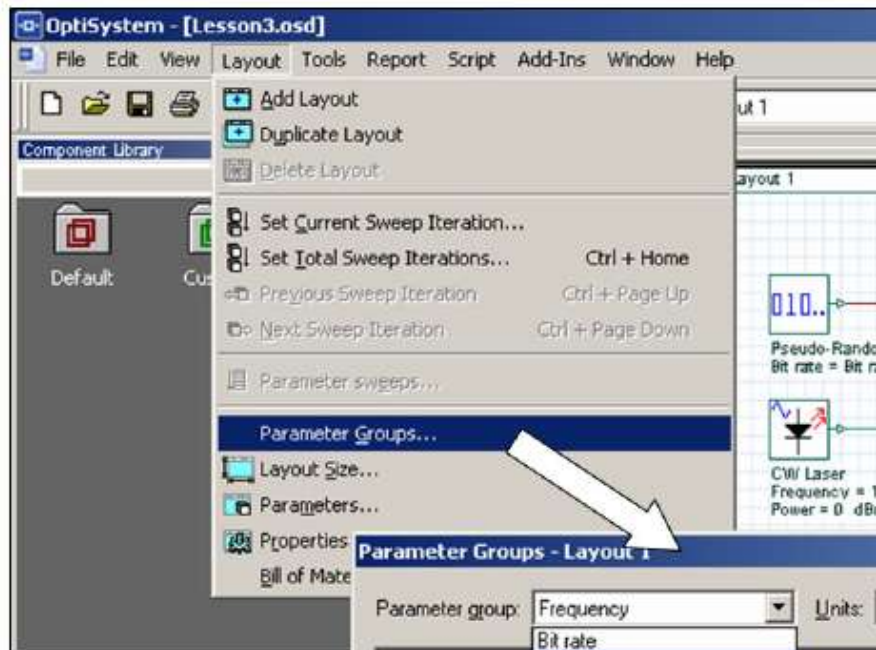
Gerenciamento da Biblioteca de Componentes



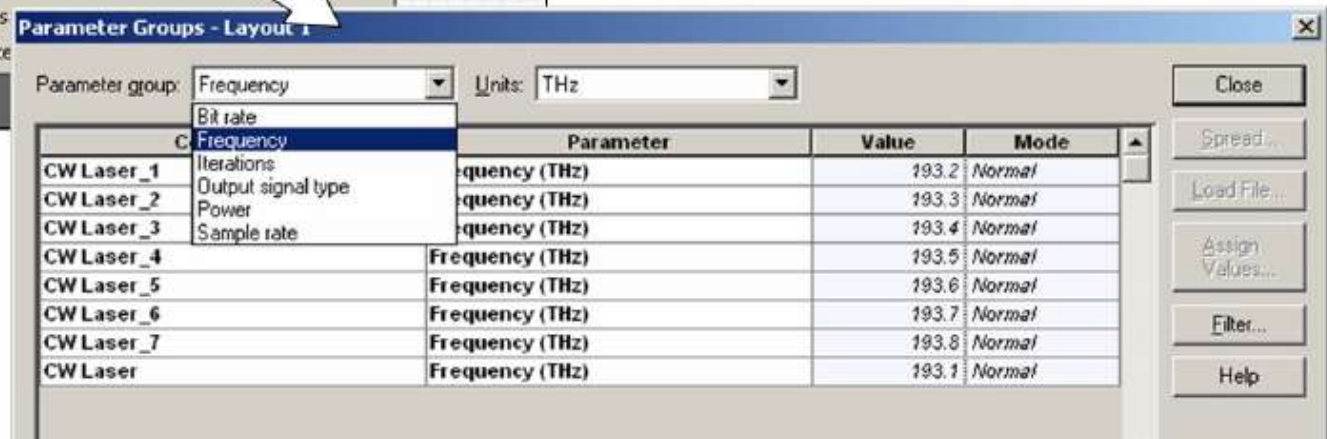
Para otimizar
espaço de
memória:
**Abilita e desabilita
bibliotecas**



Grupo de Parâmetros



Permite modificar um conjunto de valores de um parâmetro a partir de um comando





Prática 3

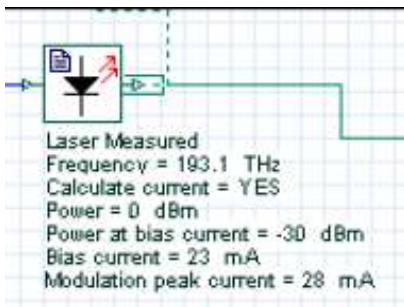
Verificar modificação nos resultados devido a modificações nos parâmetros globais



4. Modelos Implementados

- Lasers:

CW,
Pulsado,
Medido,
etc



Laser Measured Properties

Label: Laser Measured Cost\$: 0.00

Main
 Measure...
 Physical
 Initial esti...
 Simulation
 Noise
 Random n...

Disp	Name	Value	Units	Mode
<input checked="" type="checkbox"/>	Frequency	193.1	THz	Normal
<input type="checkbox"/>	Calculate current	<input checked="" type="checkbox"/>		Normal
<input checked="" type="checkbox"/>	Power	0	dBm	Normal
<input type="checkbox"/>	Power at bias current	-30	dBm	Normal
<input type="checkbox"/>	Bias current	23	mA	Normal
<input type="checkbox"/>	Modulation peak current	28	mA	Normal

Buttons: OK, Cancel, Evaluate Script, Load..., Save As..., Security..., Help



Diferentes Modelos para um Mesmo Dispositivo

Optical

Raman

Raman Amplifier.....	235
Raman Amplifier—Average power model	251
Raman Amplifier—Dynamic model	261

EDFA

EDFA Black Box.....	271
EDF Dynamic — Full model.....	283
EDF Dynamic — Analytical model	289
EDFA.....	295
EDFA Ideal.....	303
EDFA Measured.....	309
Erbium doped fiber.....	315
Er-Yb codoped fiber	353
Er-Yb codoped waveguide amplifier	363

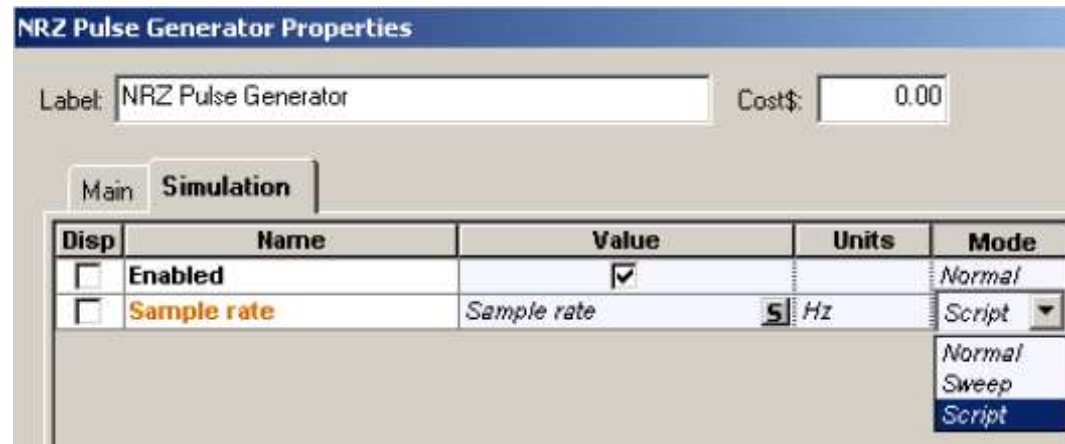
SOA

Semiconductor Optical Amplifier.....	381
--------------------------------------	-----

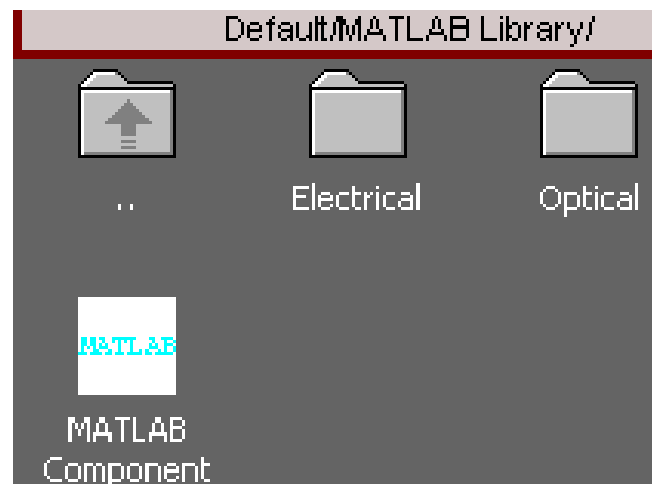


Inserir Modelo Próprio

Script



Co-Simulação



Usando a Função Script

```
'Get Layout Manager.
Dim Lm
Set Lm = Document.GetLayoutMgr

'SCRIPT for Version 1

'Get Current Layout.
Dim Layout1
Set Layout1 = Lm.GetCurrentLayout
Layout1.Name = "Version 1"
'Set Total Sweep Iterations
Layout1.SetTotalSweepIterations(10)
'Set Current Sweep Iteration
Layout1.SetCurrentSweepIteration(10)
'Get Current Canvas.
Dim Canvas1
Set Canvas1 = Layout1.GetCurrentCanvas
'SCRIPT for Layout global parameters.
Layout1.SetParameterMode "Simulation window", 0
Layout1.SetParameterValue "Simulation window", "Set bit rate"
Layout1.SetParameterMode "Reference bit rate", 0
Layout1.SetParameterValue "Reference bit rate", TRUE
Layout1.SetParameterMode "Bit rate", 0
Layout1.SetParameterValue "Bit rate", 1e+010
Layout1.SetParameterMode "Time window", 0
Layout1.SetParameterValue "Time window", 2.56e-008
Layout1.SetParameterMode "Sample rate", 0
Layout1.SetParameterValue "Sample rate", 1.28e+012
Layout1.SetParameterMode "Sequence length", 0
Layout1.SetParameterValue "Sequence length", 256
Layout1.SetParameterMode "Samples per bit", 0
```

Permite modificar:

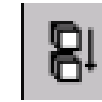
- parâmetros globais
- layout
- parâmetros de componentes



Prática 4

- 4a. Localizar a biblioteca de lasers
- 4b. Caracterizar 3 diferentes tipos de lasers existentes na biblioteca de lasers

5. Variando Parâmetros Automaticamente (*Sweep*)



Layout Tools Report Script Add-Ins Window Help

- Add Layout
- Duplicate Layout
- Delete Layout
- Set Current Sweep Iteration...
- Set Total Sweep Iterations... Ctrl + Home
- Previous Sweep Iteration Ctrl + Page Up
- Next Sweep Iteration Ctrl + Page Down
- Parameter sweeps...
- Parameter Groups...
- Layout Size...
- Parameters...
- Properties...
- Bill of Materials...

Total Parameter Sweep Iterations

Total iterations:

Current iteration:

OK Cancel

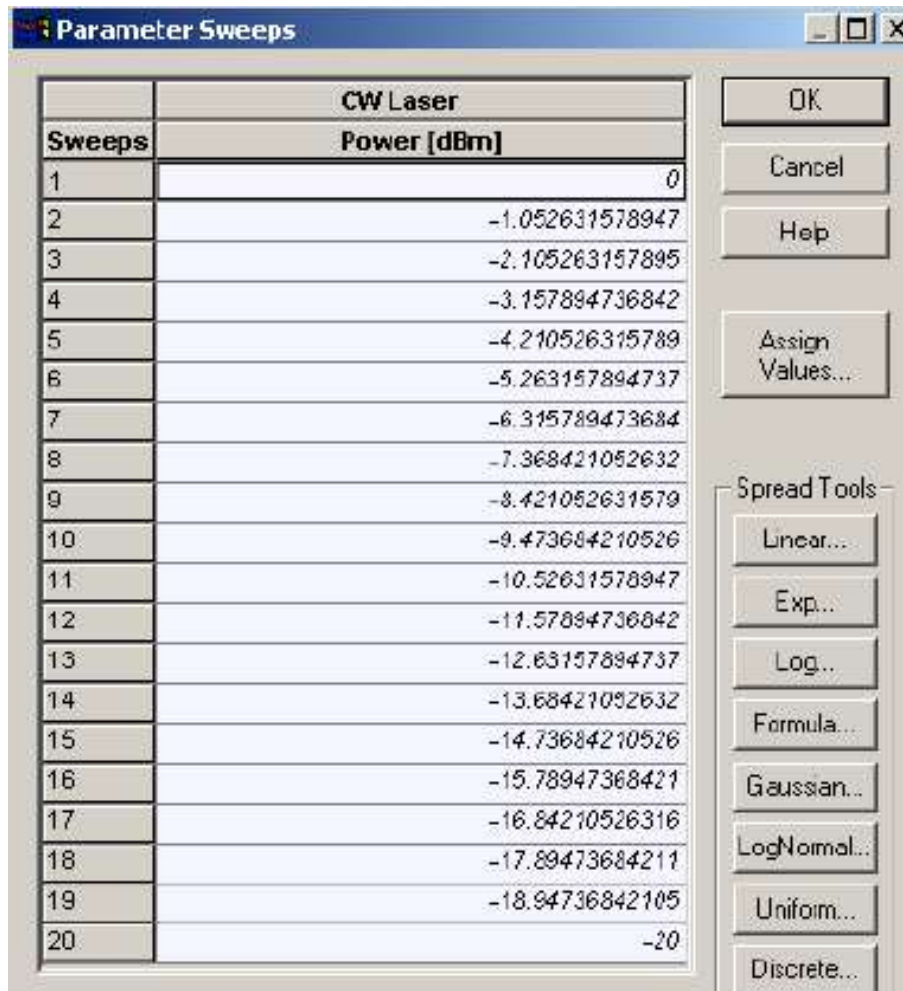
CW Laser Properties

Label: CW Laser Cost: 0.00

OK Cancel Evaluate Script

Disp	Name	Value	Units	Mode
<input checked="" type="checkbox"/>	Frequency	1576.315789474	nm	Normal
<input checked="" type="checkbox"/>	Power	-13.68421052632	dBm	Sweep
<input type="checkbox"/>	Linewidth	10	MHz	Normal
<input type="checkbox"/>	Initial phase	0	deg	Normal

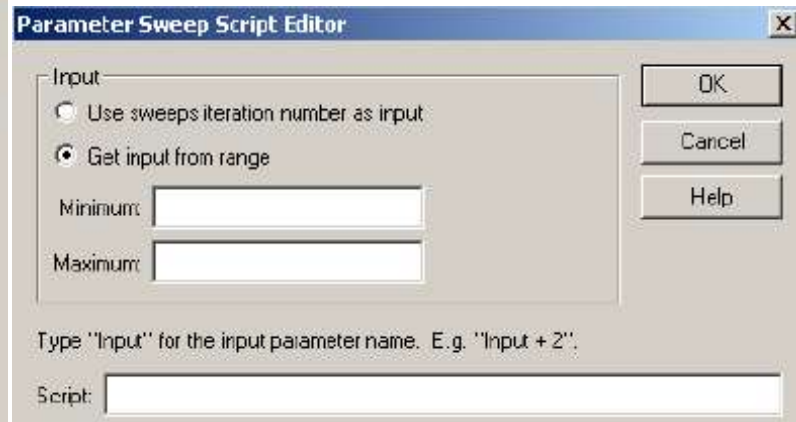
Selecionando o Intervalo de Variação



Parameter Sweeps

Sweeps	CW Laser Power [dBm]
1	0
2	-1.052631578947
3	-2.105263157895
4	-3.157894736842
5	-4.210526315789
6	-5.263157894737
7	-6.315789473684
8	-7.368421052632
9	-8.421052631579
10	-9.473684210526
11	-10.52631578947
12	-11.57894736842
13	-12.63157894737
14	-13.68421052632
15	-14.73684210526
16	-15.78947368421
17	-16.84210526316
18	-17.89473684211
19	-18.94736842105
20	-20

Buttons: OK, Cancel, Help, Assign Values..., Spread Tools (Linear..., Exp..., Log..., Formula..., Gaussian..., LogNormal..., Uniform..., Discrete...)



Parameter Sweep Script Editor

Input:

Use sweeps iteration number as input

Get input from range

Minimum:

Maximum:

Type "Input" for the input parameter name. E.g. "Input + 2".

Script:

Buttons: OK, Cancel, Help



Gaussian sweep iteration

Random seed index:

Format for Std. Dev: absolute %

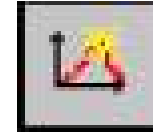
Normal Value:

Std. Dev:

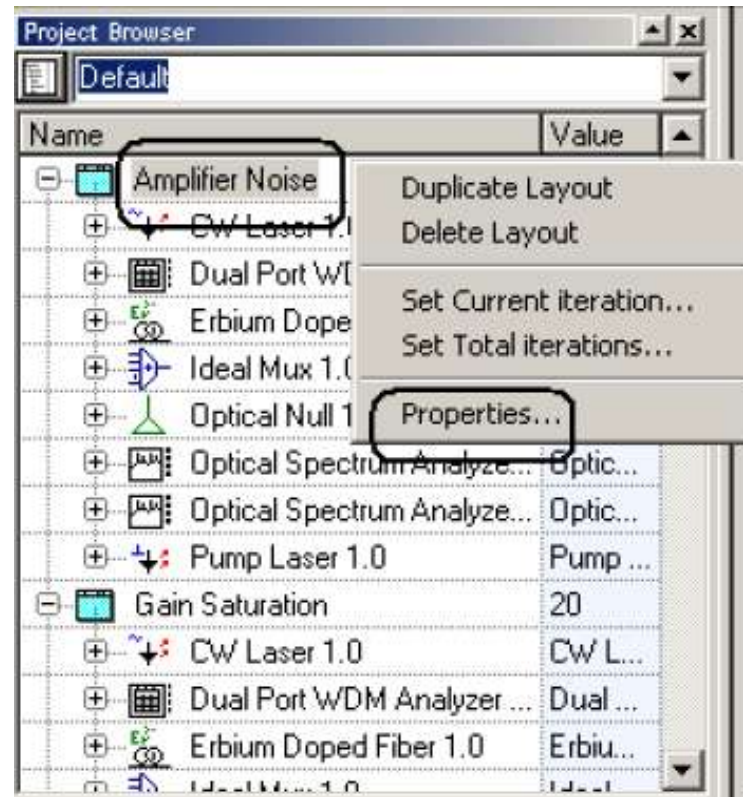
Buttons: OK, Cancel



6. Rotinas de Otimização

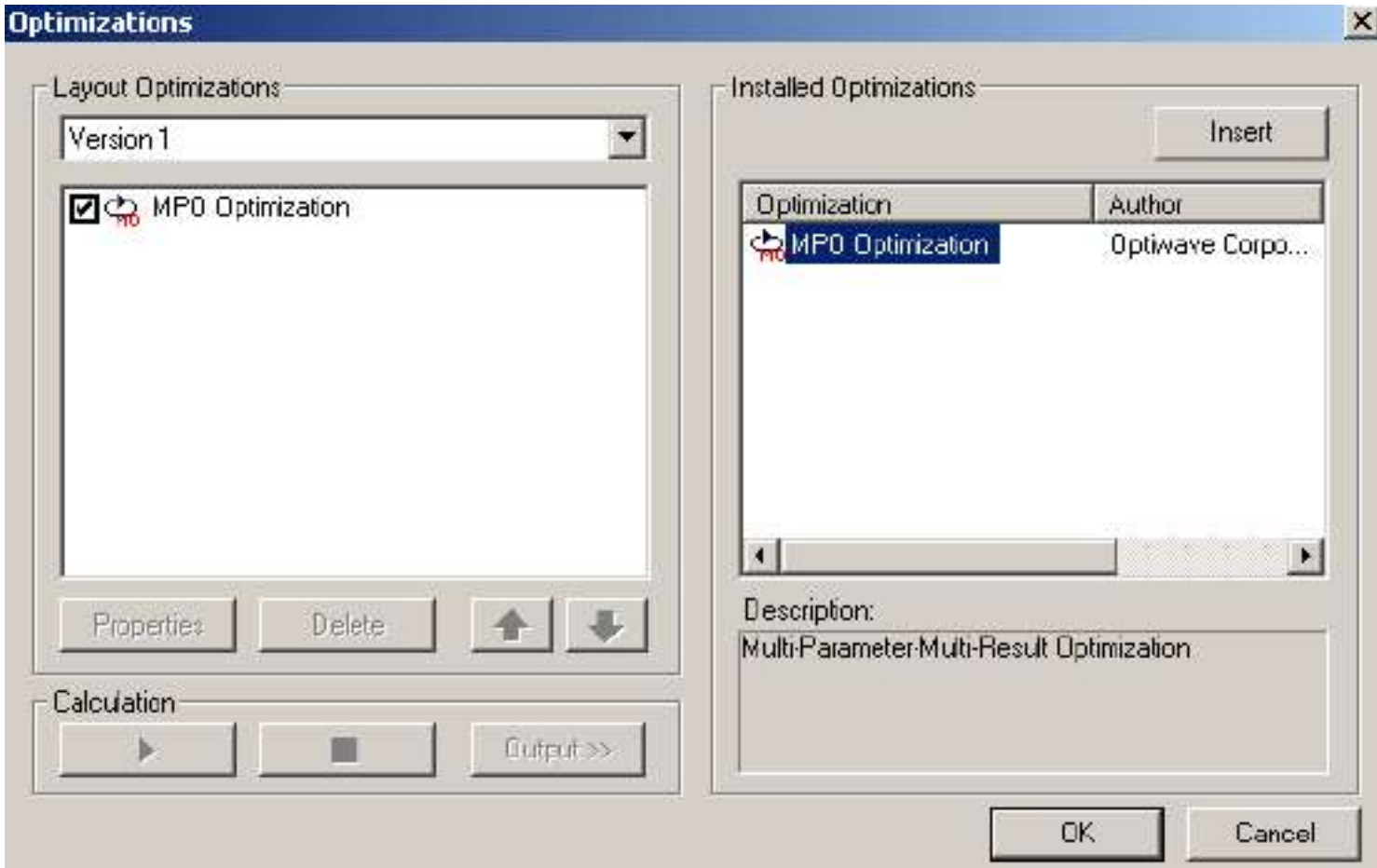


- *Um único parâmetro*
- *Multi-parâmetros*
- . *Parâmetros*
- . *Resultados*





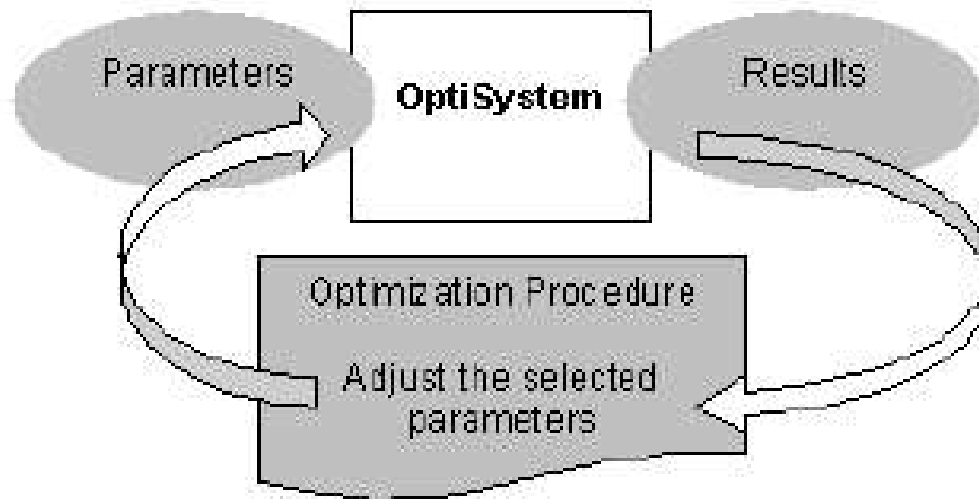
Como Realizar a Otimização





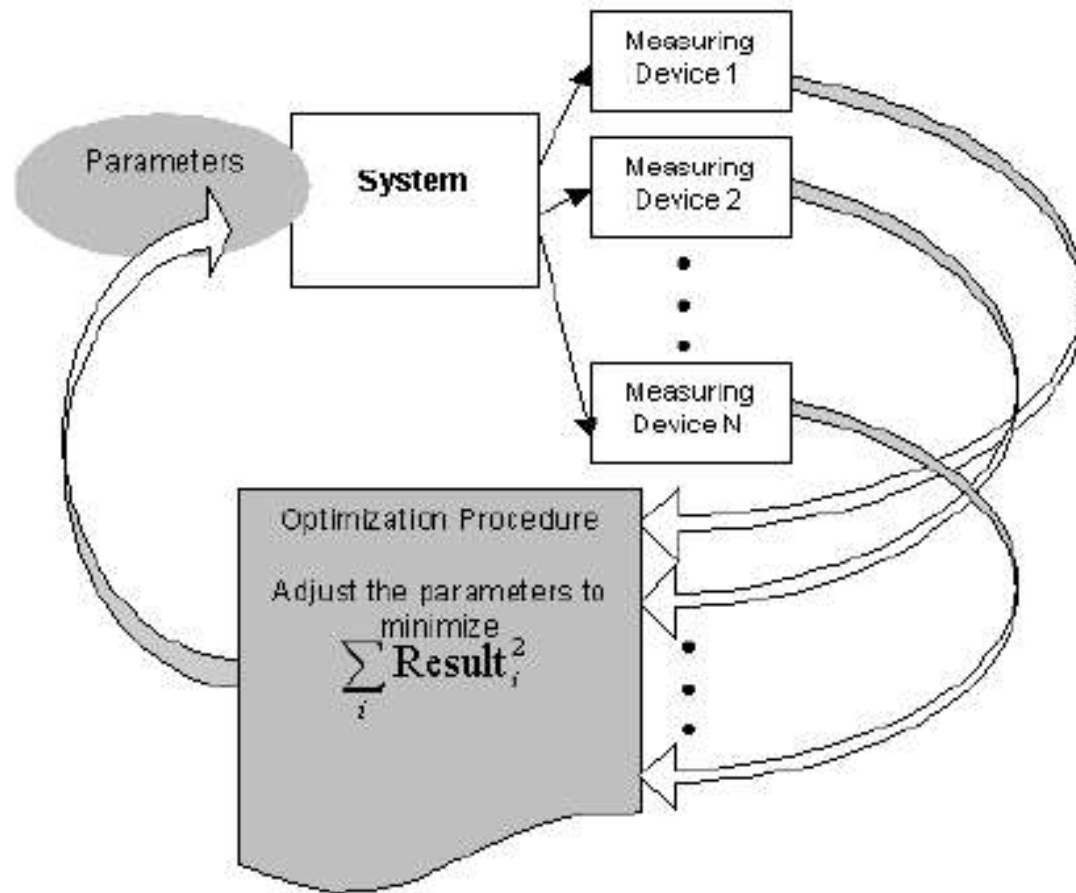
Otimização Multiparâmetro

Minimiza
Maximiza
Busca valor alvo



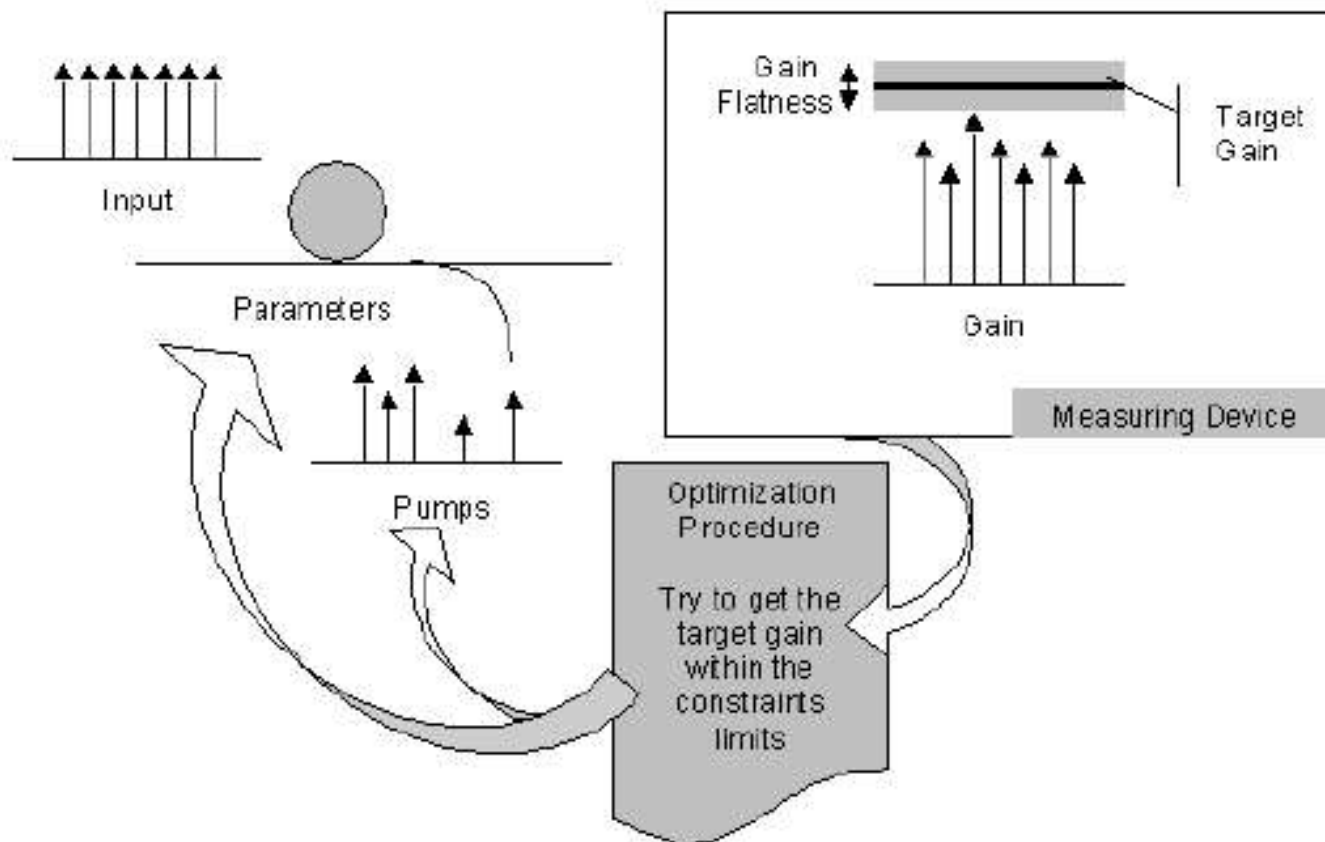


Nonlinear Fitting





Otimização para Obter Ganho Plano





Iniciando Otimização

Setup

Optimization Name:

Main | Parameters | Results | Advanced

Optimization

Optimization Type:

Goal Attainment:

Maximum number of passes:

Result Tolerance for Exact Goal Attainment (%):

Constrained

General Info

Author:

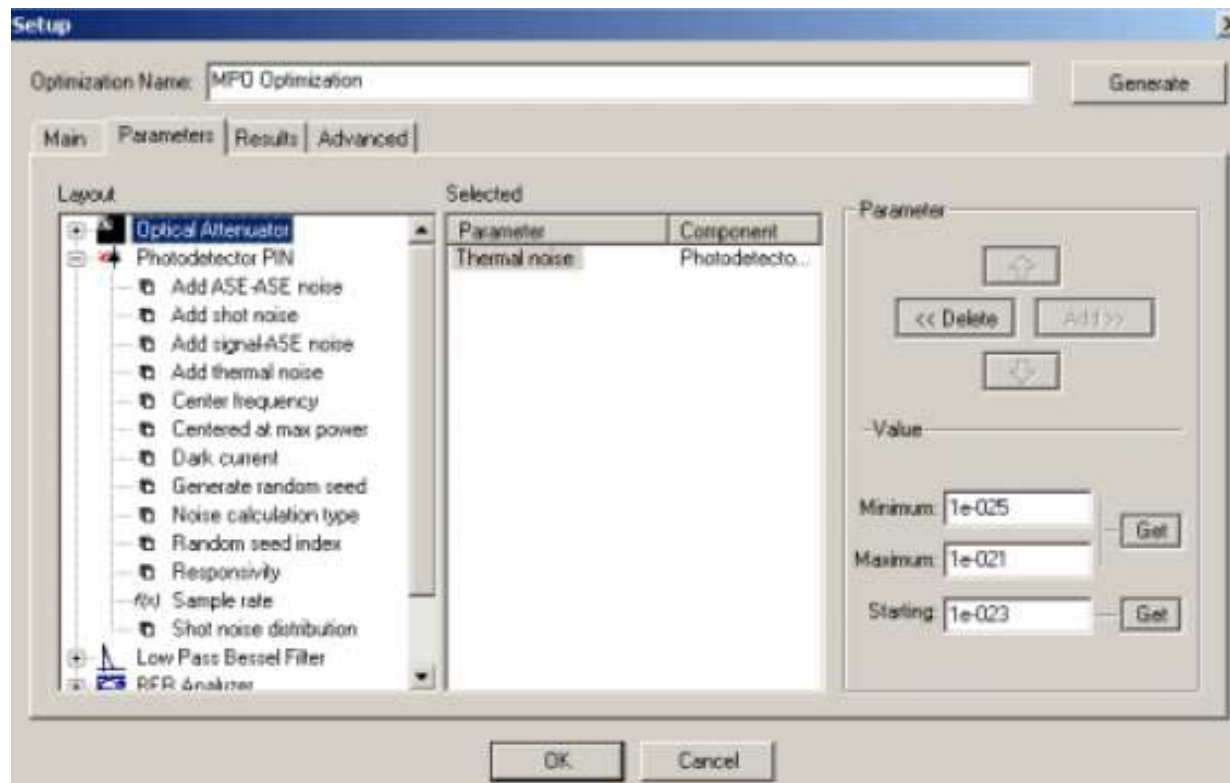
Version:

Copyright:

Description:

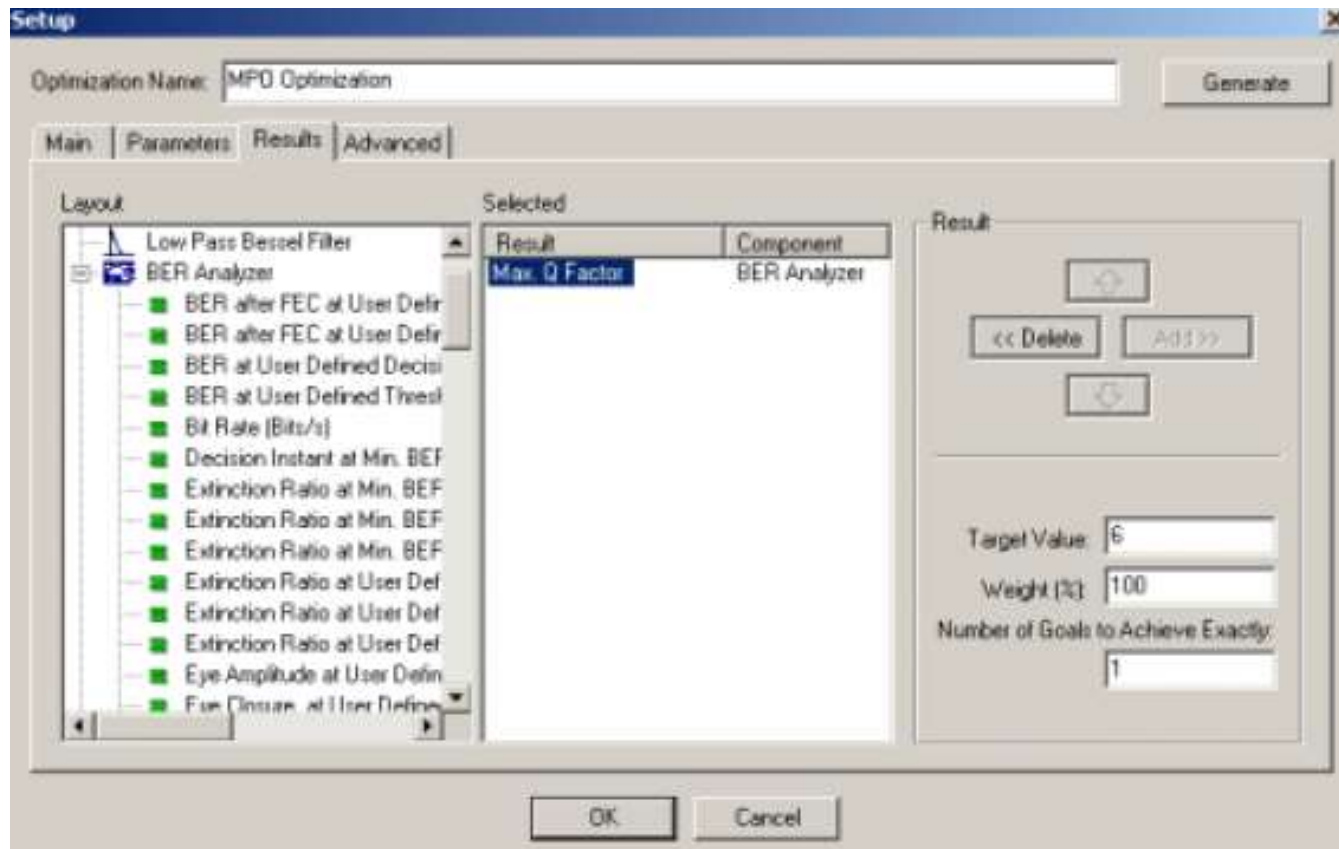


Selecionando Parâmetros





Resultados Desejados





Adicionando Restrições





Parâmetros e Resultados Seleccionados

Select Parameters

Selected Parameters		Constraint	
Parameter	Component	Parameter	Component
Calculate parameters	Laser Measured	Σ Calculate 3D graph	BER Analyzer

Select Results

Layout Results		Selected Result	
Result	Component	Result	Component
Bit Rate (Bits/s)		Threshold at Min. BER...	BER Analyzer
Decision Instant at Min. BER (bit p			
Extinction Ratio at Min. BER			
Extinction Ratio at Min. BER (%)			
Extinction Ratio at Min. BER (dB)			
Extinction Ratio at User Defined D			
Extinction Ratio at User Defined D			
Extinction Ratio at User Defined D			
Eye Amplitude at User Defined De			
Eye Closure at User Defined Deci			
Eye Height at User Defined Decisi			
Eye Opening Factor at User Defini			
Eye Opening Factor at User Defini			
Eye Opening Factor at User Defini			
log of BER after FEC at User Defir			
log of BER after FEC at User Defir			
log of BER at User Defined Decisi			



7. Visualizadores: Eléctricos e Ópticos

- **Ópticos**

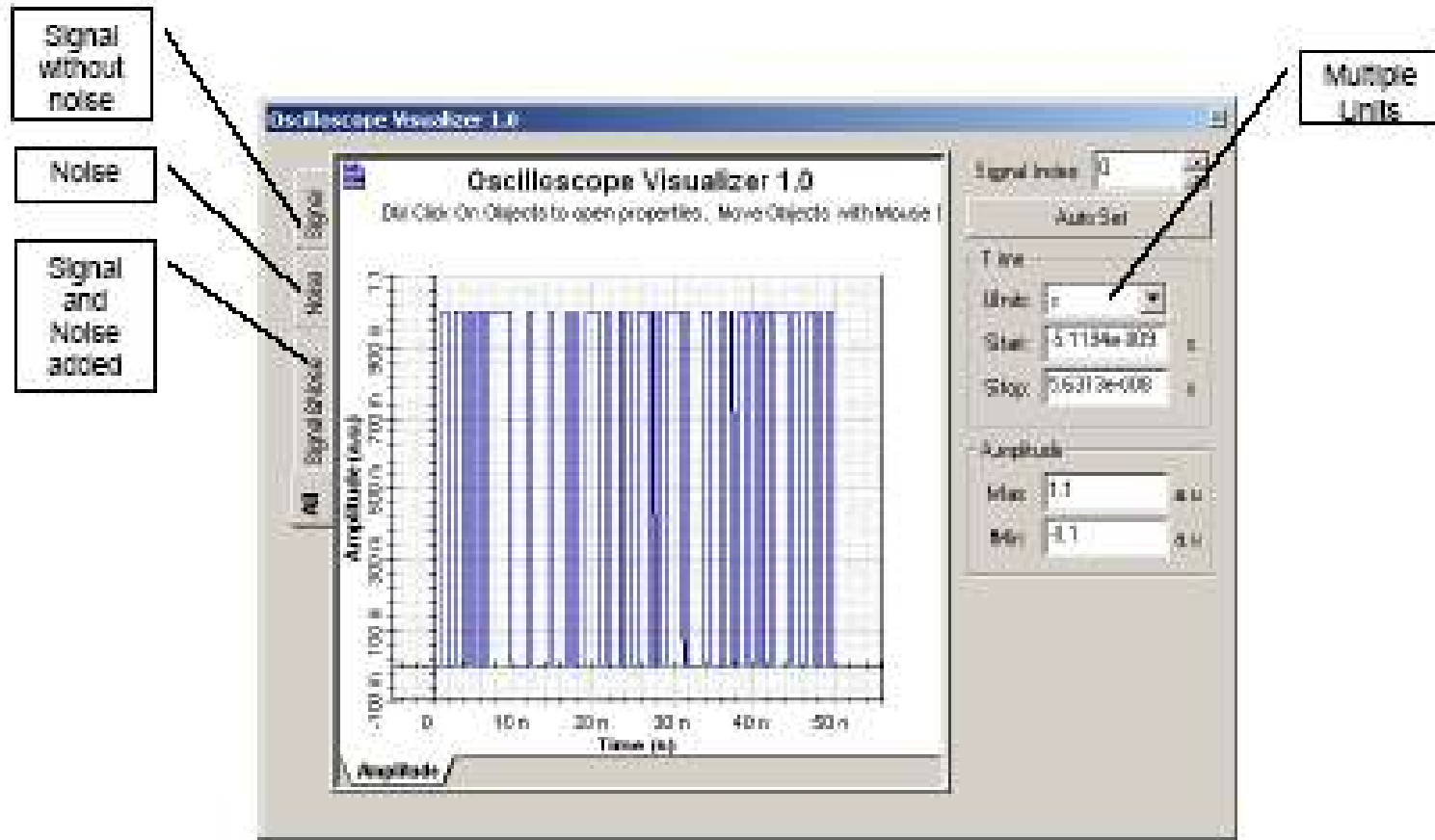
- OSA;
- Visualizador no Domínio do Tempo;
- Medidor de Potência Óptica;
- Analisador WDM de Duas Portas;

- **Eléctricos**

- Osciloscópio;
- Analisador de Espectro;
- Analisador de Diagrama de Olho;



Osciloscópio



Analizador WDM de Duas Portas

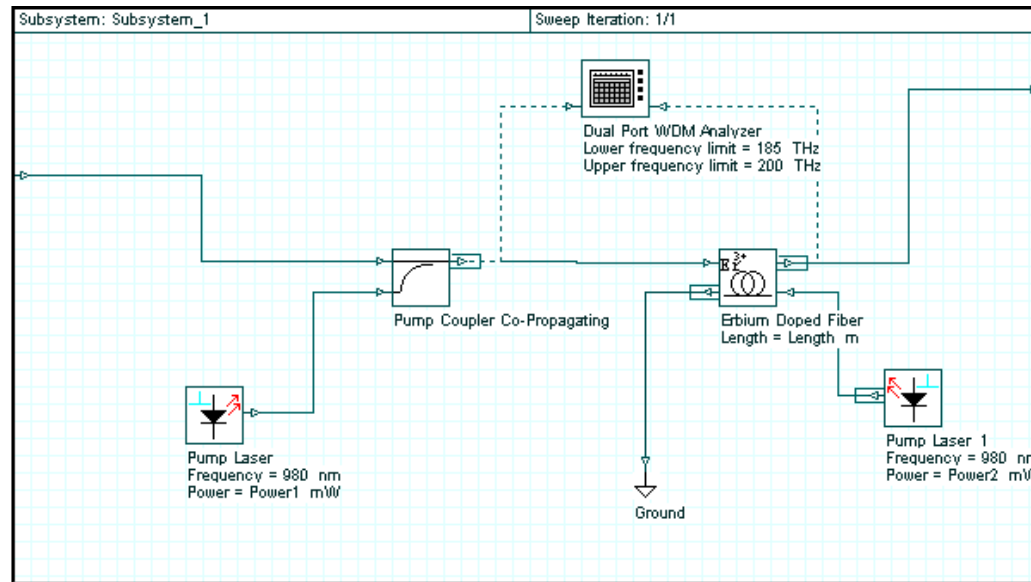


Tabela com Resultados Calculados

Frequency (THz)	Gain (dB)	Noise Figure (dB)	Input Signal (dBm)	Output Signal (dBm)	Output Noise (dBm)	Output OSNR (dB)
193.1	29.76227	4.21943	-30.3357	-0.57345	-23.9805	23.4071
193.3	30.017895	4.1469	-30.5583	-0.5404	-23.7929	23.2525
193.5	30.192835	4.30219	-31.095	-0.902136	-23.458	22.5559
193.7	30.416544	4.35884	-31.6104	-1.19383	-23.1731	21.9793

Analysis / Details



Analizador de Espectro

Óptico e Elétrico

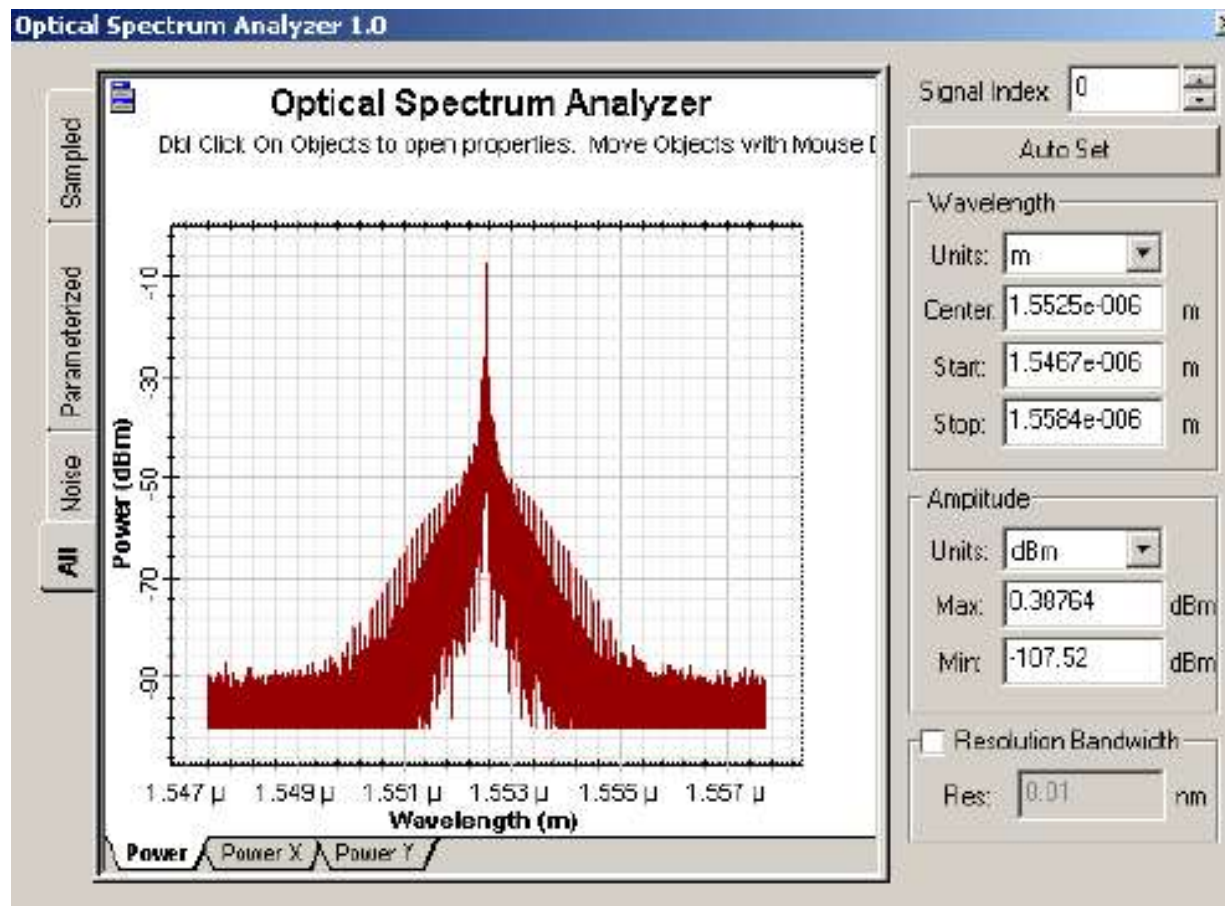
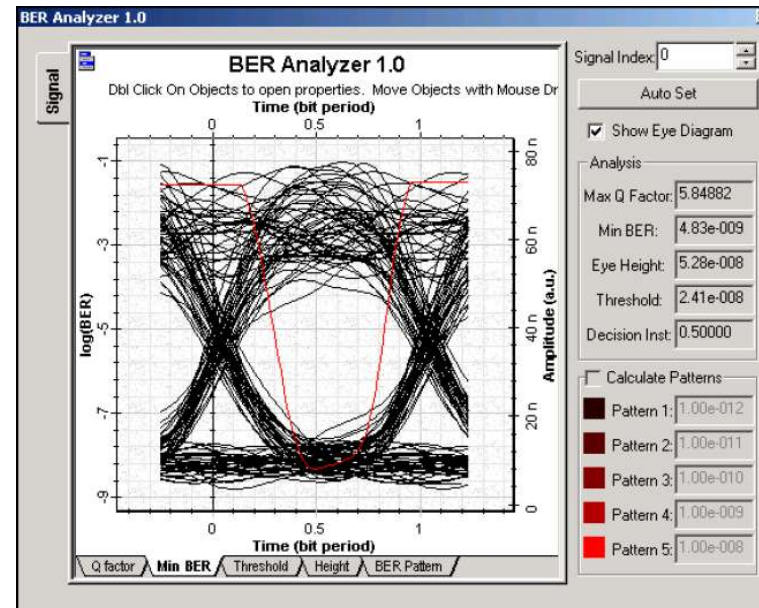
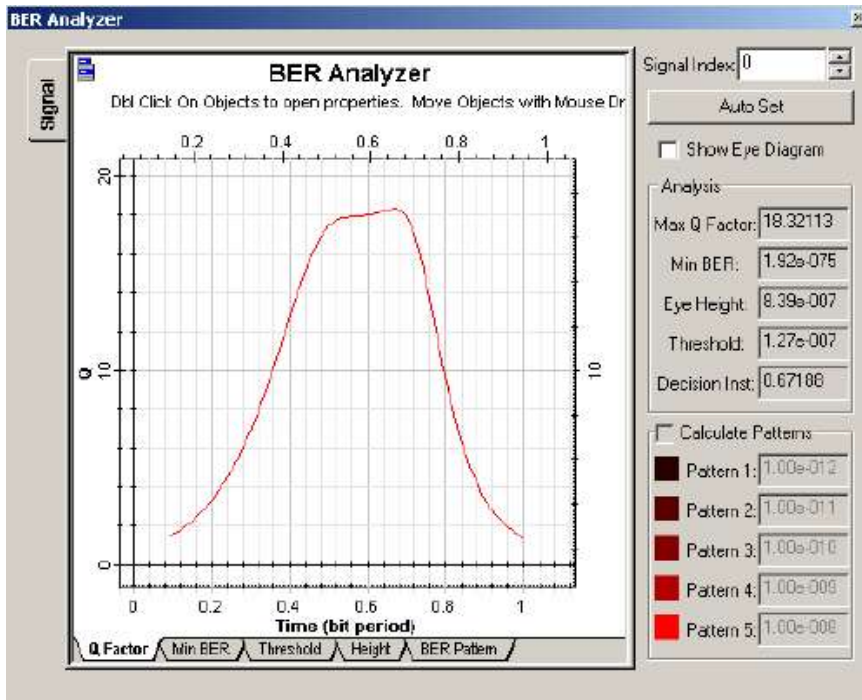




Diagrama de Olho e BER

Analysis

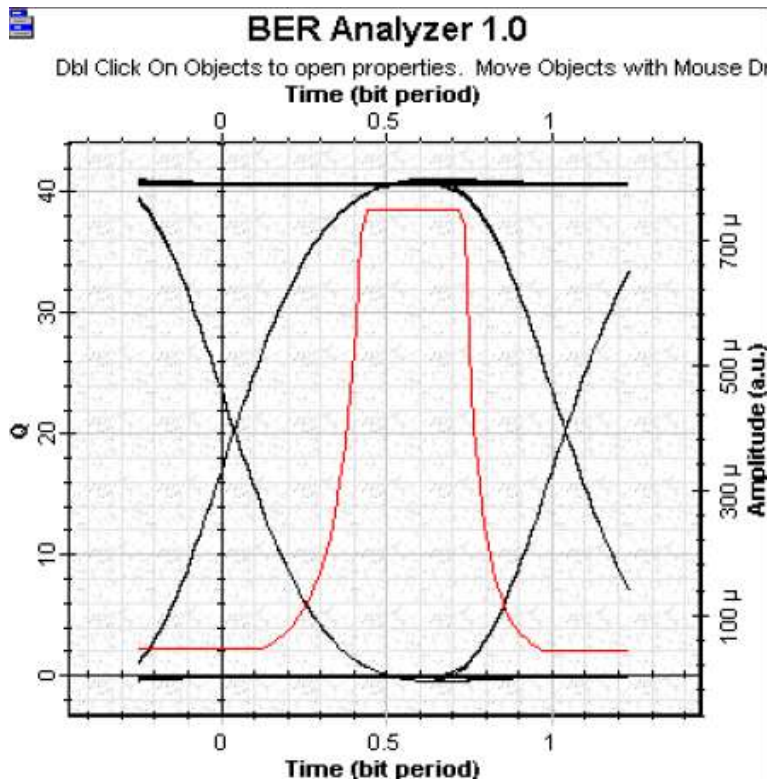
Max Q Factor:	6.02842
Min BER:	8.24e-010
Eye Height:	1.26e-005
Threshold:	1.20e-005
Decision Inst:	0.47461



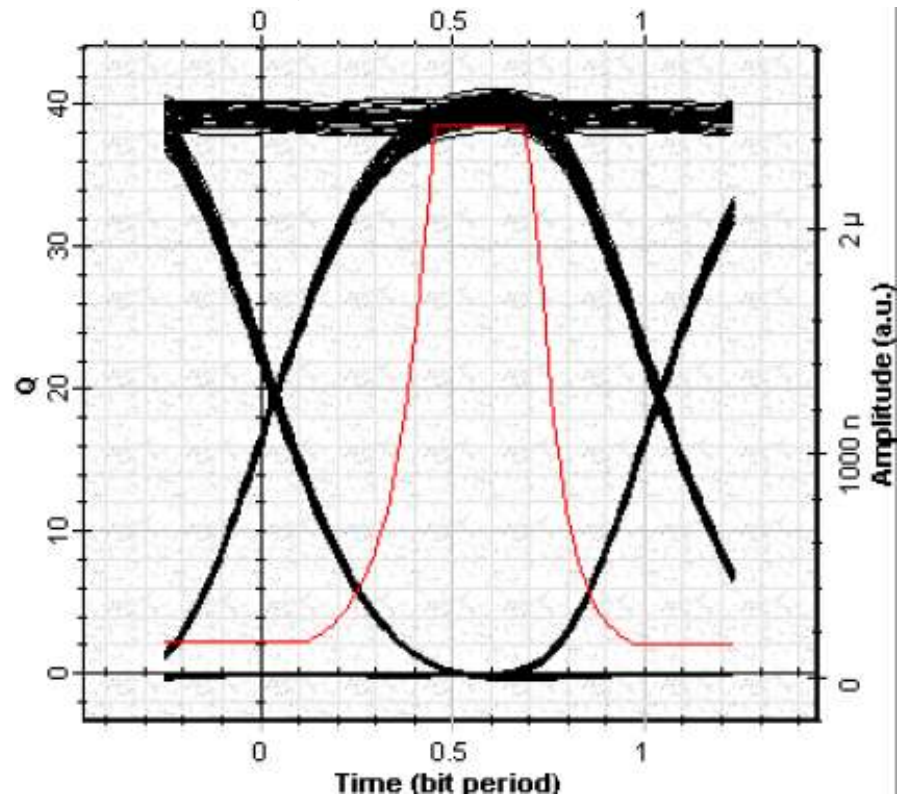


Fator Q

$$L_{fibra} = 0 \text{ km}$$



$$L_{fibra} = 100 \text{ km}$$





Exportar Curvas Calculadas

The screenshot displays the 'Optical Spectrum Analyzer 1.0' software. The main window shows a spectral plot with a red curve. A 'Data Table' dialog box is open, showing a list of data points. An arrow points from the 'Table of Points' option in the software's menu to the 'Data Table' dialog. Another arrow points from the 'Export to File' button in the 'Data Table' dialog to the 'Export to File' dialog box, which is open and shows the file name 'Curve.xls' and the save location 'My Documents'.

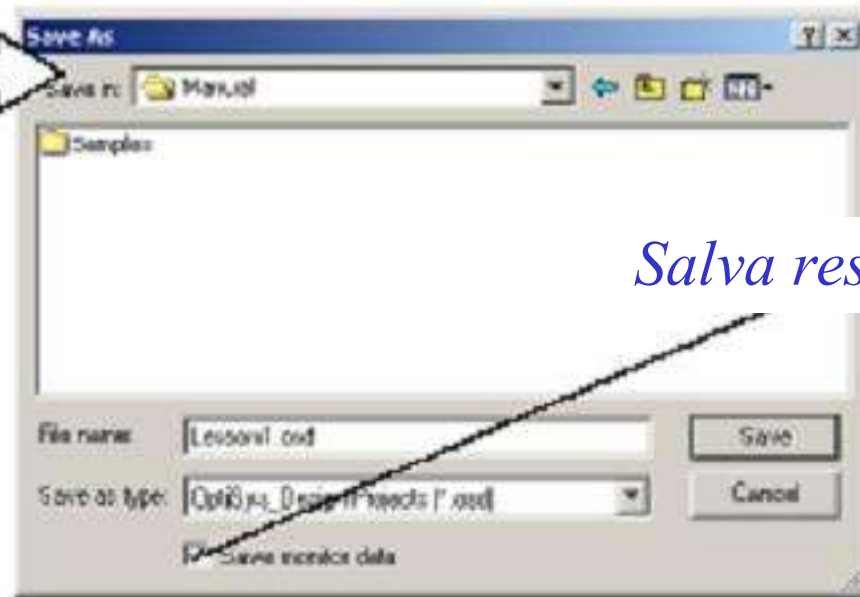
X Values	Y Values
1.55126e+000	84.6200
1.55206e+000	86.1240
1.55286e+000	88.6484
1.55366e+000	90.8900
1.55446e+000	93.8670
1.55526e+000	97.4607
1.55606e+000	101.751
1.55686e+000	106.6907
1.55766e+000	112.2000
1.55846e+000	118.2000
1.55926e+000	124.7000
1.56006e+000	131.7000
1.56086e+000	139.2000
1.56166e+000	147.2000
1.56246e+000	155.7000
1.56326e+000	164.7000
1.56406e+000	174.2000
1.56486e+000	184.2000
1.56566e+000	194.7000
1.56646e+000	205.7000
1.56726e+000	217.2000
1.56806e+000	229.2000
1.56886e+000	241.7000
1.56966e+000	254.7000
1.57046e+000	268.2000
1.57126e+000	282.2000
1.57206e+000	296.7000
1.57286e+000	311.7000
1.57366e+000	327.2000
1.57446e+000	343.2000
1.57526e+000	359.7000
1.57606e+000	376.7000
1.57686e+000	394.2000
1.57766e+000	412.2000
1.57846e+000	430.7000
1.57926e+000	449.7000
1.58006e+000	469.2000
1.58086e+000	489.2000
1.58166e+000	509.7000
1.58246e+000	530.7000
1.58326e+000	552.2000
1.58406e+000	574.2000
1.58486e+000	596.7000
1.58566e+000	619.7000
1.58646e+000	643.2000
1.58726e+000	667.2000
1.58806e+000	691.7000
1.58886e+000	716.7000
1.58966e+000	742.2000
1.59046e+000	768.2000
1.59126e+000	794.7000
1.59206e+000	821.7000
1.59286e+000	849.2000
1.59366e+000	877.2000
1.59446e+000	905.7000
1.59526e+000	934.7000
1.59606e+000	964.2000
1.59686e+000	994.2000
1.59766e+000	1024.7000
1.59846e+000	1055.7000
1.59926e+000	1087.2000
1.59999e+000	1119.2000



Salvando Resultados Simulados



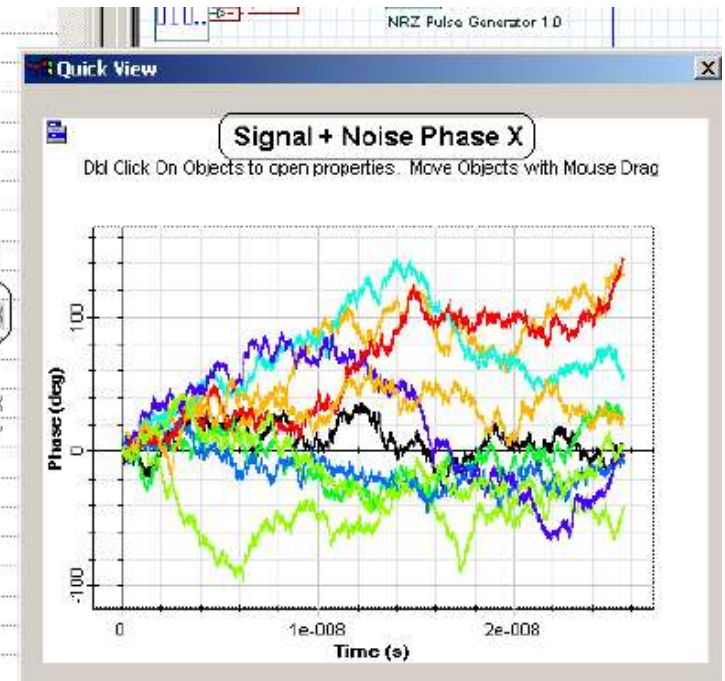
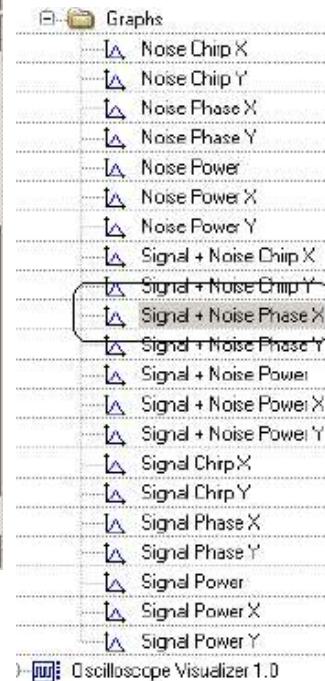
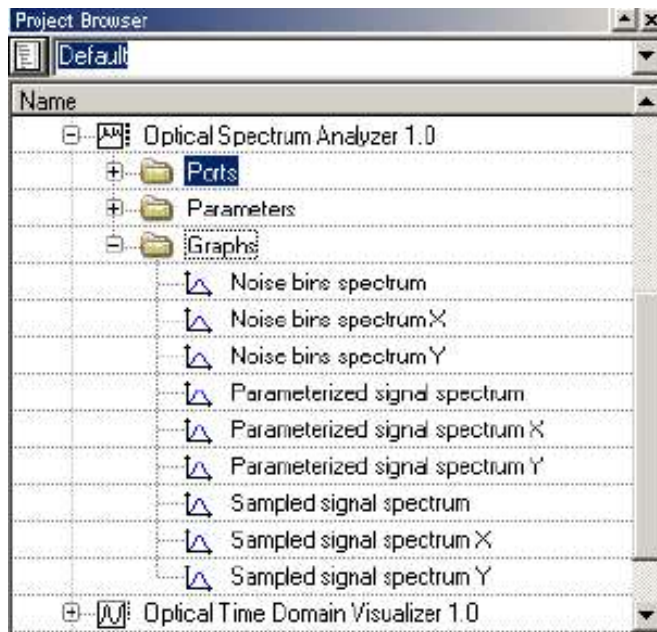
Requer mais memória



Salva resultados



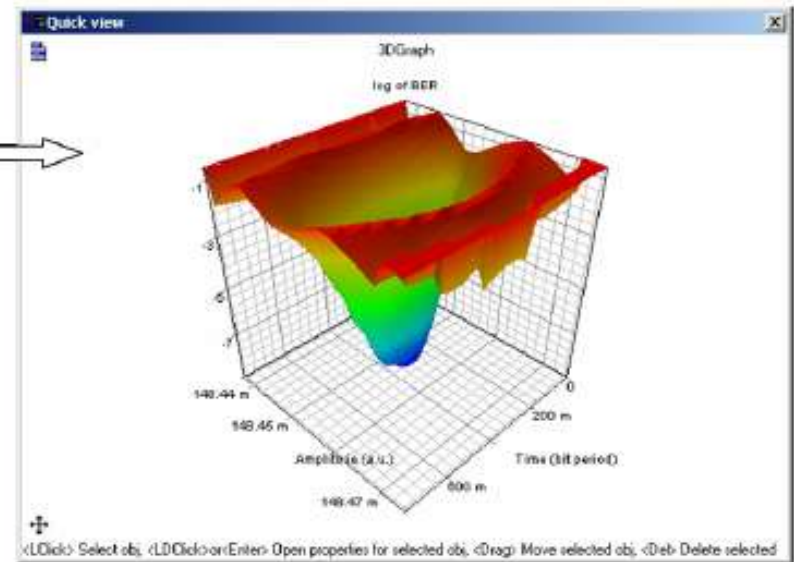
Gráficos Adicionais em *Project Browser*





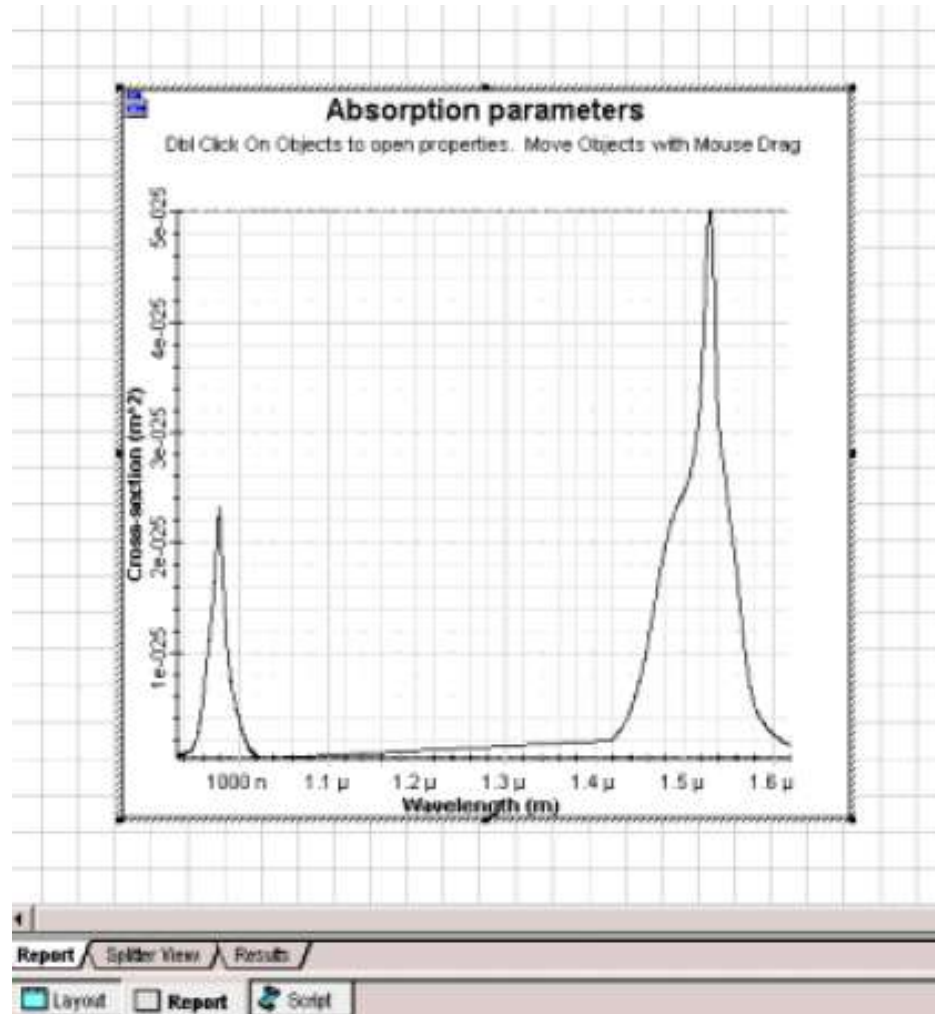
Gráficos 3D

*Habilitar em Component
Propertiers*



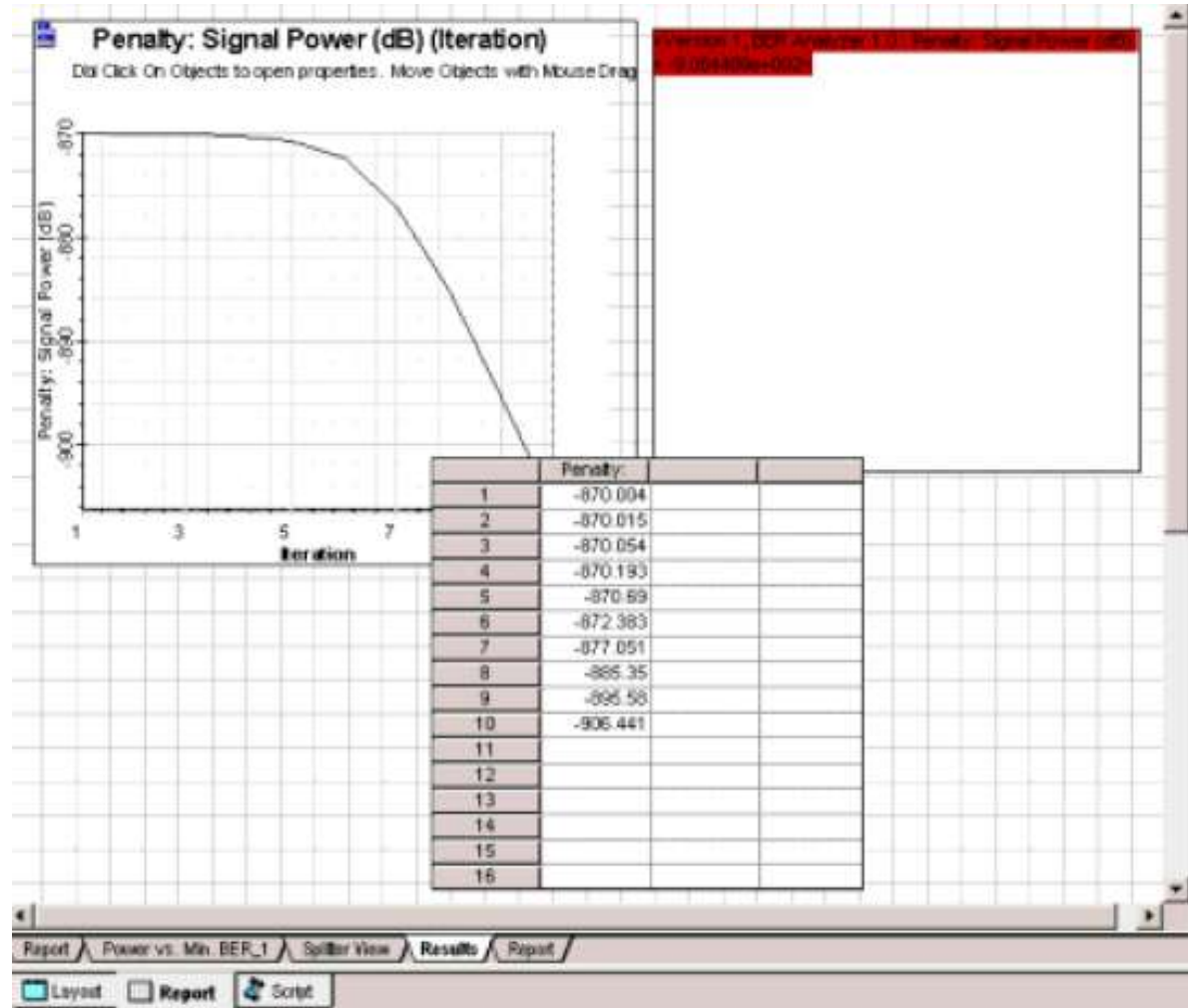


Construindo Gráficos no *Report Window*



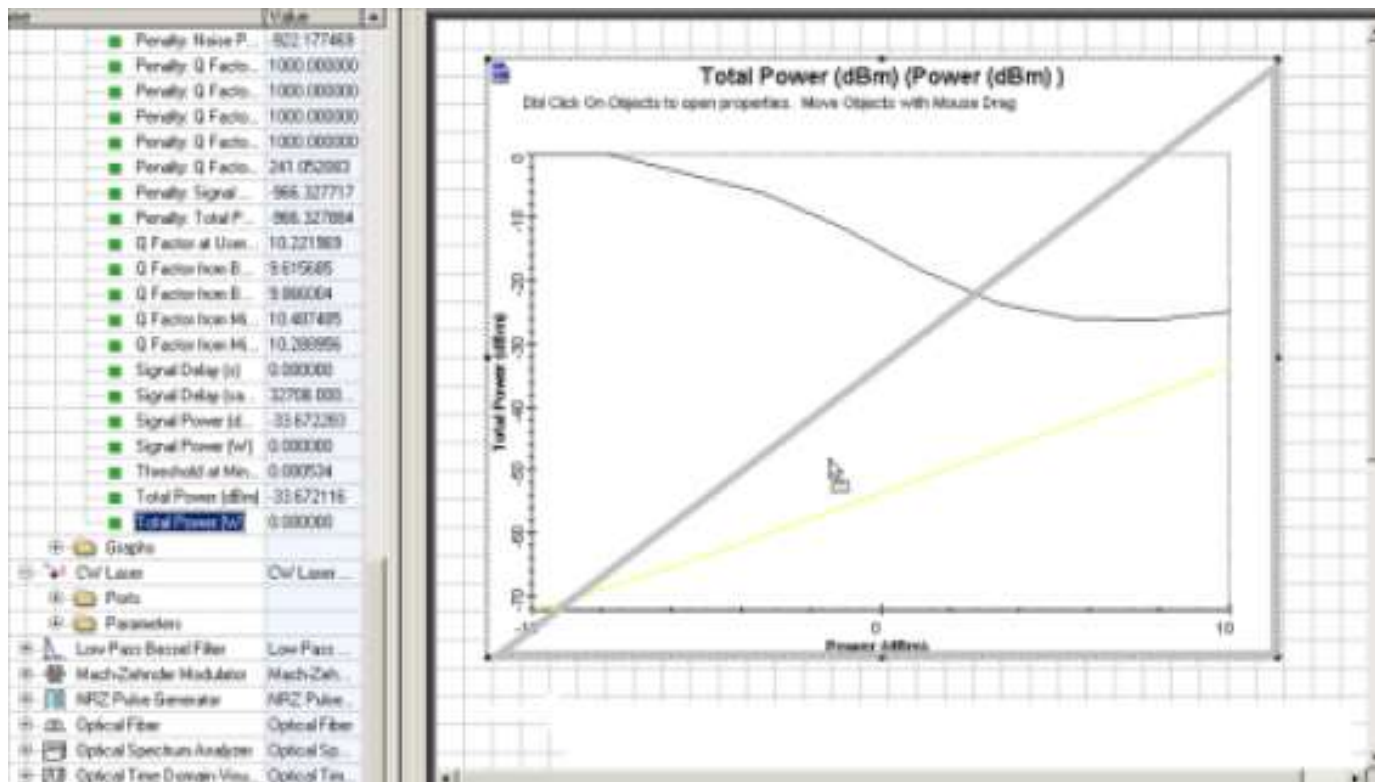


Formas de Apresentar Resultados



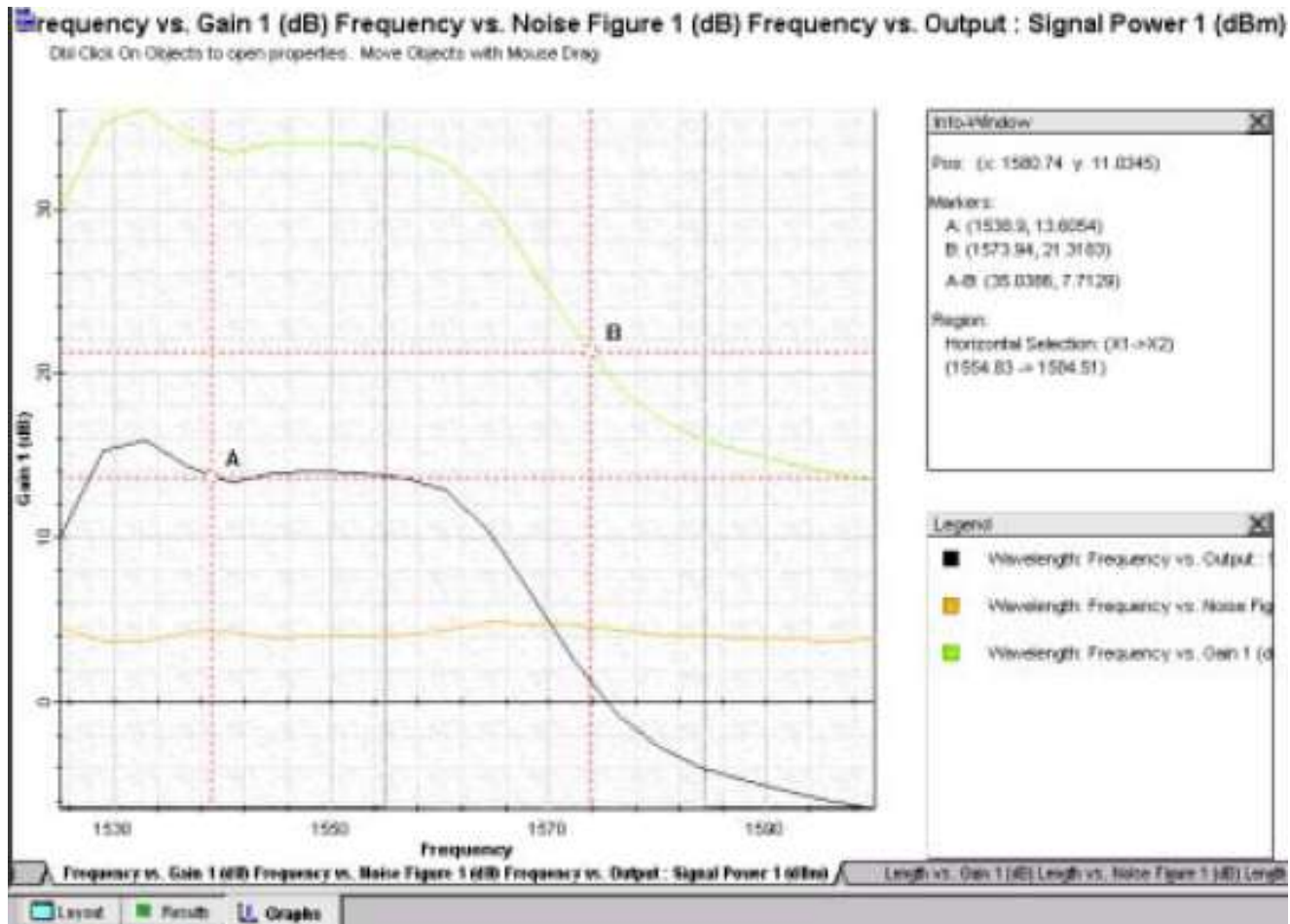


Plotando Parâmetros com Resultados





Controle de Gráficos





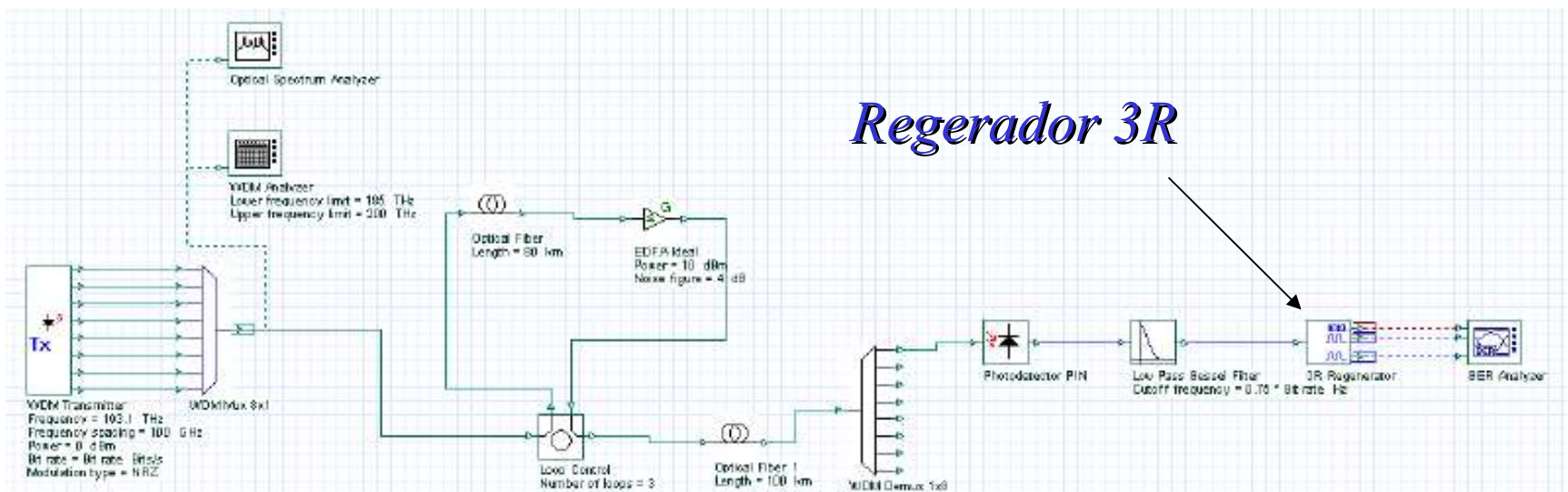
Prática 5

Usando a janela “Report” construir o gráfico da BER em função da potência de sinal de entrada no receptor para um sistema ponto-a-ponto



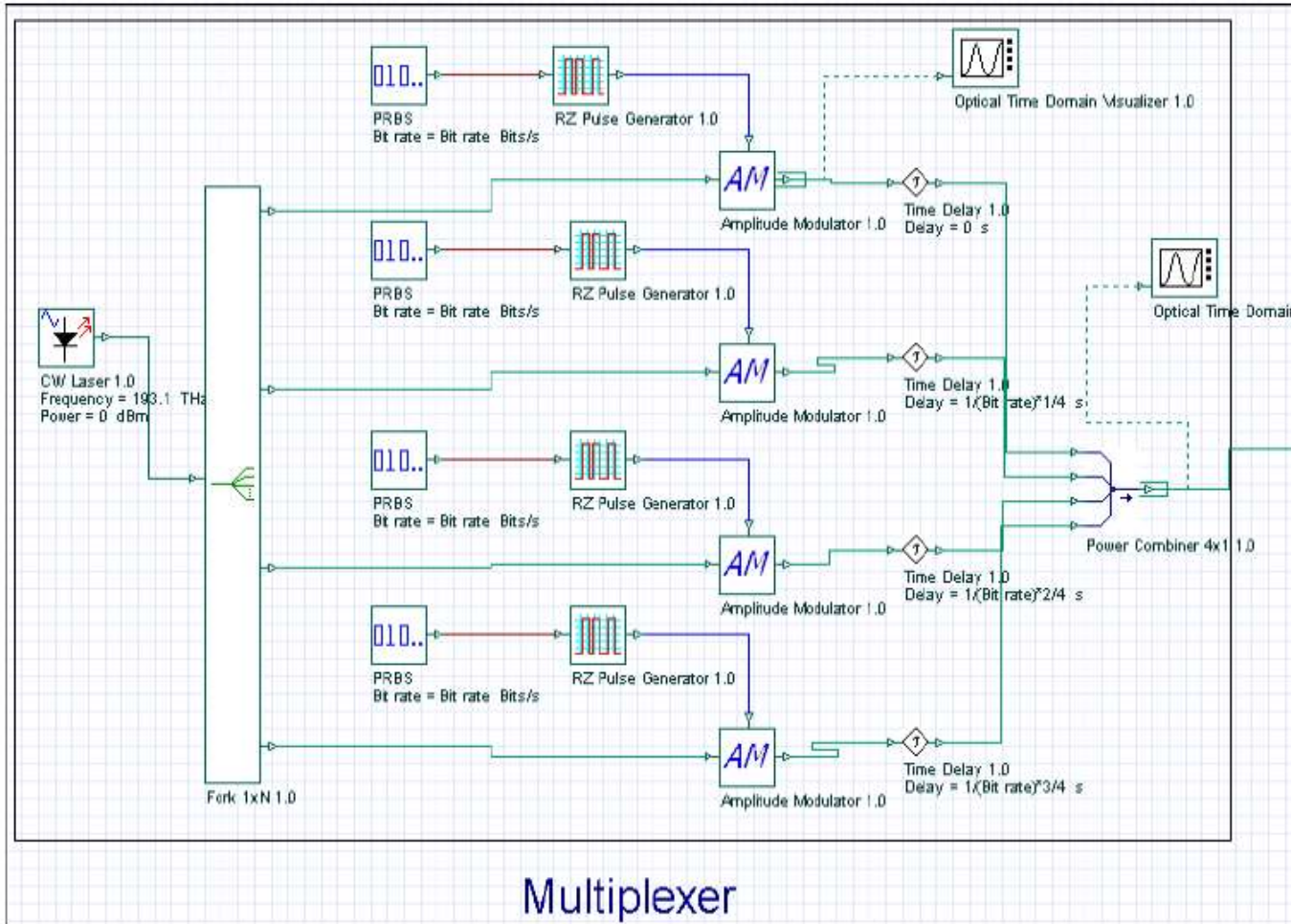
8. Exemplos:

Sistemas WDM





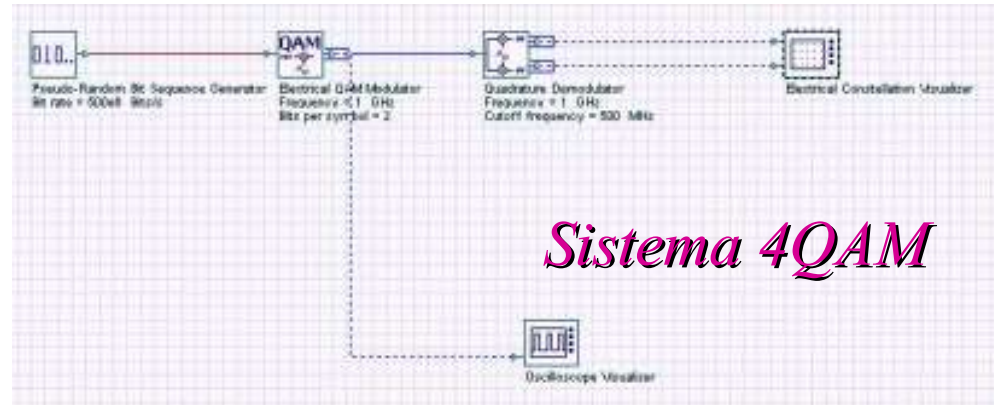
Sistemas OTDM





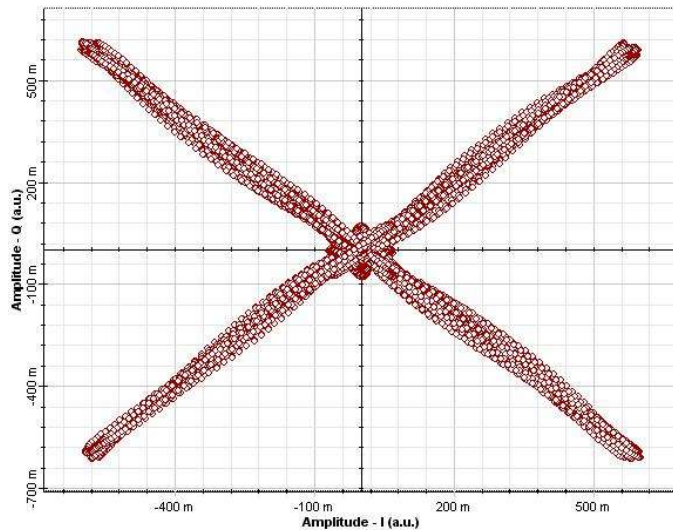
Sistemas SCM

Cable Access Library



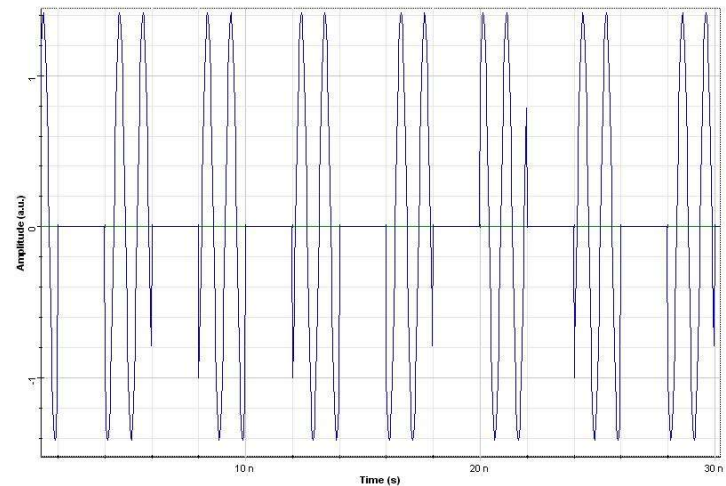
Electrical Constellation Visualizer

dbl Click On Objects to open properties. Move Objects with Mouse Drag



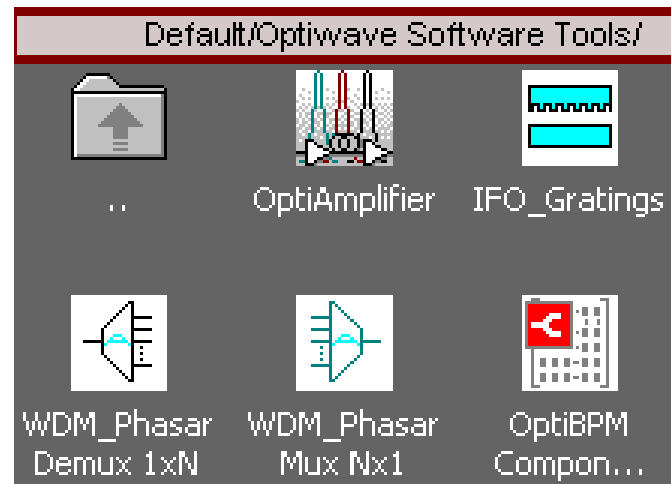
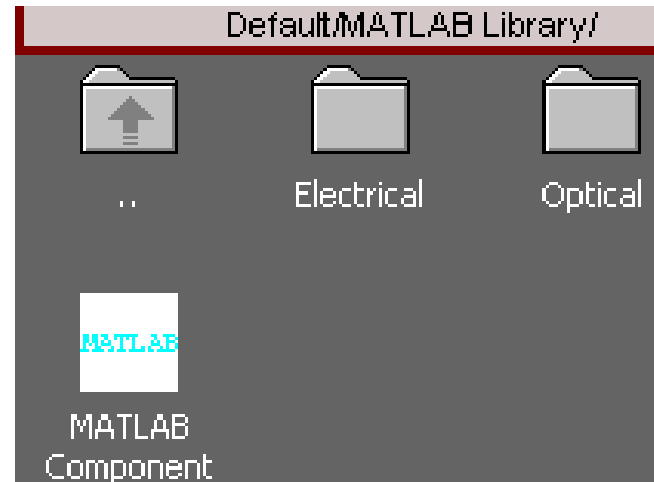
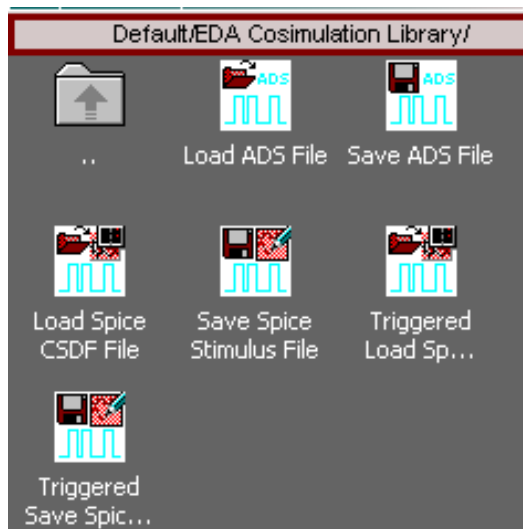
Oscilloscope Visualizer

Left Button and Drag to Select Zoom Region. Press Control Key and Left Mouse Button To Zoom Out.





Cosimulação



Estimativa de Custo do Layout

Subsystem 1 Properties

Label: Subsystem 1 Cost\$: 0.00

Image

Disp	Name	Value	Units	Mode
<input type="checkbox"/>	Subsystem Representatio	GlassBox Image		Normal
<input type="checkbox"/>	Image Filename	...		Normal
<input type="checkbox"/>	Stretch Image	<input type="checkbox"/>		Normal

Bill of Materials

Component Name	Cost
Laser Measured	0.000000
Pseudo-Random Bit Sequence Generat	0.000000
NRZ Pulse Generator	0.000000
Photodstector PIN	0.000000
Low Pass Bessel Filter	0.000000
Optical Attenuator	0.000000
Oscilloscope Visualizer	0.000000
Optical Spectrum Analyzer	0.000000
Optical Time Domain Visualizer	0.000000
BER Analyzer	0.000000
Total Cost	0.000000



9. Comentários Finais

- Documentação Disponível
(*Getting Started*, Tutorial, *User Reference*, Biblioteca de Componentes, *Visual Basic Reference*)
- Tempo de Processamento
- Exemplos com diferentes aplicações