Educational Tool for Optical Communications Engineering Teaching

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Abstract: - This paper presents a software tool developed for simulating optical communications systems. The optical system is divided into three main parts: transmitter, optical fibber and receiver. The simulation allows the determinations of the spectral and frequency responses of each block and the whole system. The program allows the simulations of the different types and generations of optical systems in a user friendly environment. The tool has been developed using MATLAB 6 and is suitable for educational purpose.

Key-Words: - Optical System, Simulation Software, Education, Fibber

1 Introduction

The practice of educational experiments on systems of optical communications requires the acquisition of high cost measurement instruments and for those we don't usually have funds.

The practical teaching can be carried out measuring with simple equipment, such as sources and hand power meters and completing them with simulation programs that allow more ambitious experiments.

The main inconvenience of the commercial software systems is that they don't have the most appropriate educational focus for the engineering students. For this reason, it is interesting the development of a tool that allows, with a friendly and accessible environment for the student, the study of the optical communication systems.

For the use of this tool it is not necessary to have knowledge of a programming language. The user interaction is carried out in a graphic and intuitive way.

2 Optical System Modelling

The study of optical communications systems also implies the knowledge of its historical evolution. This allows understanding the limitations of the components that have formed them and the advantages contributed by the technology advances.

The tool that we present allows the user to study five typical systems or generations (Table 1). [1], [2], [3], [4].

The first step that the students should give is to select one of the generations from the table 1. Then, the generation window appears showing a blocks diagram and a configuration menu bar by means of which the students will determine the characteristics of each one of the elements that constitute this generation.

Generation	Main features
First	LED and multimode fibber. Pulse transmission.
Second	LED or LASER and monomode fibber. Pulse transmission.
Third	LASER and monomode fibber. Pulse transmission.
Fourth	LASER and monomode fibber. Digital modulation signal
Fifth	LASER and wavelength division multiplexing. Optical amplification.

Table 1. Main features of optical generations.

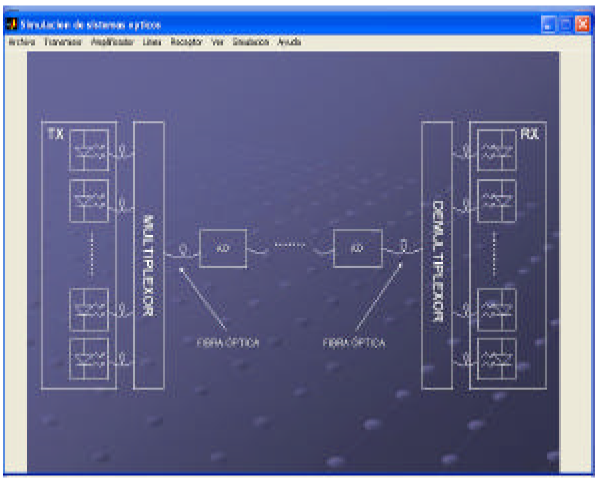

Fig. 1. Fifth generation configuration window

We have assumed in the simulation that the three basic blocks of our optical system are lineal (emitter, fibber and receiver). If we note each one of the single transfer function as H_{Tx}, H_{fibber} y H_{Rx}, the whole response is given by (1).

$$H(f) = H_{Tx} H_{fibber} H_{Rx} \quad (1)$$

This global response allows knowing the system capacity of transmission, the mean photodetected power half is obtained carrying out the power budget of the connection. [1], [2], [3], [4].

2.1 Optical transmitter response

The program allows to simulate led or laser transmitters. The laser frequency response can be chosen of first or second order. Moreover, we can choose between monomode and multimode laser type. (Fig.2)

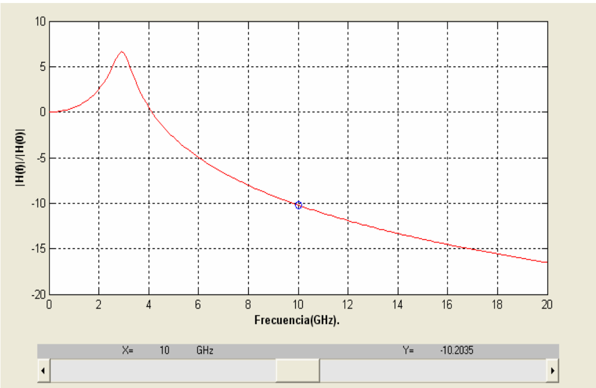

Fig. 2. Laser transfer function.

The user can specify the main optic characteristics of the light source: emission wavelength, spectral width, MSR, etc. [9], [10], [15], [16]

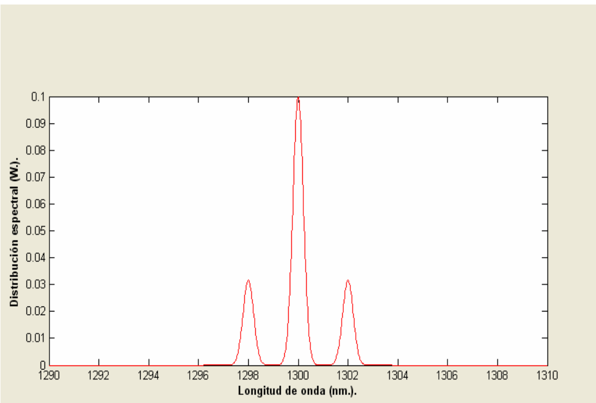

Fig.3. Multimode laser spectrum

2.2 Fiber optic modelling

The fibber optic response models its attenuation and chromatic dispersion. The attenuation has been calculated starting from the attenuations of the silica in the infrared, the Rayleigh dispersion and the impurities absorptions, especially the OH ions.

The developed tool represents the attenuation graphically. It allows demonstrating the student the importance of the manufacturing process of the fibber. The students can introduce the amount of the OH concentration manually or to select the fibber type among the ITU-T standards. The figure 4 shows an example of the attenuation of a fibber with low OH concentration.

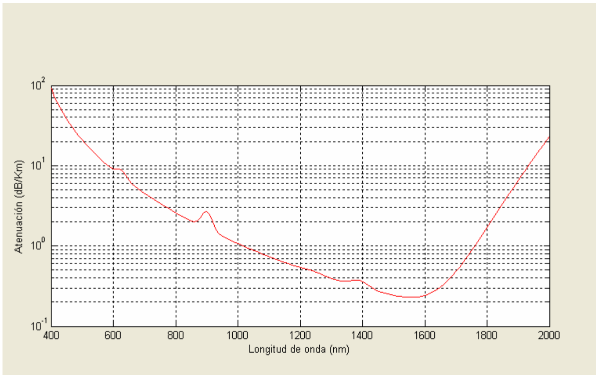

Fig.4. Low OH fibber attenuation

The second necessary parameter to characterize fibber optic is the bandwidth. For it, we have to consider the dispersion effects. The necessary data for the calculation are taken from the ITU-T recommendations. In the case of multimode fibber, we consider the longitude and bandwidth product. If the fibbers are monomode, the polynomials of Sellmeier are used. We also consider the PMD dispersion. [6], [9]

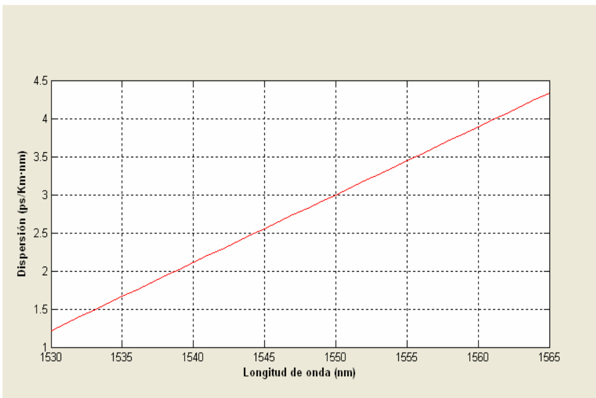

Fig. 5 Dispersion in a NZ-DSF fibber.

2.3 Optical receiver response

The types of detectors that the program allows to simulate are the PIN diode and the avalanche diode or APD. The student should introduce the relative data to cutting wavelength, efficiency, bias current, rise time… The answers offered by the program are the transfer function, the spectral response, the responsivity and the noise power. A utility has also been designed to determine the photodetecting efficiency depending on the semiconductor material chosen to carry out the detector. [5], [10], [12].

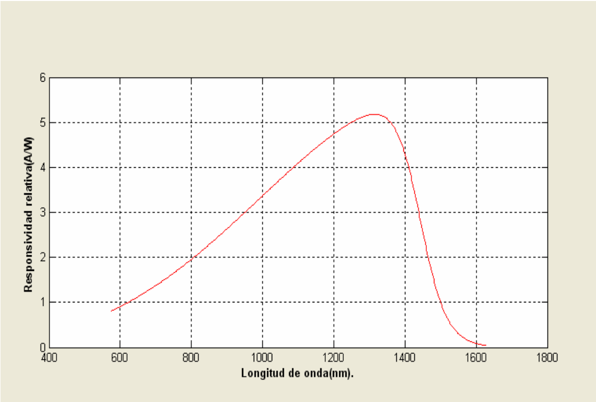

Fig. 6. APD Photodiode response.

3 Signal Transmission

Depending on the selected generation, it is possible to transmit rectangular pulses or modulated digital signals. The tool calculates the power budget of the connection. It also obtains the noise power in the receiver (optic and thermal). With these values it offers the Signal/Noise ratio (S/N) and the bit error rate (BER). To determine it, in the case of a transmitter laser, they are also used the power penalties due to extinction rate and MSR.

The program also shows the results graphically by representing it the received signal time variations as an oscilloscope. In the case of digital modulated signals it also shows the constellation of the received signal. [11], [13], [14]

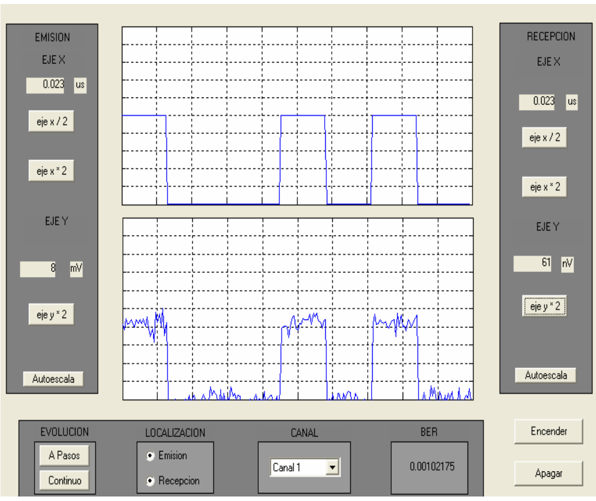

Fig. 7. Transmitted and received signals.

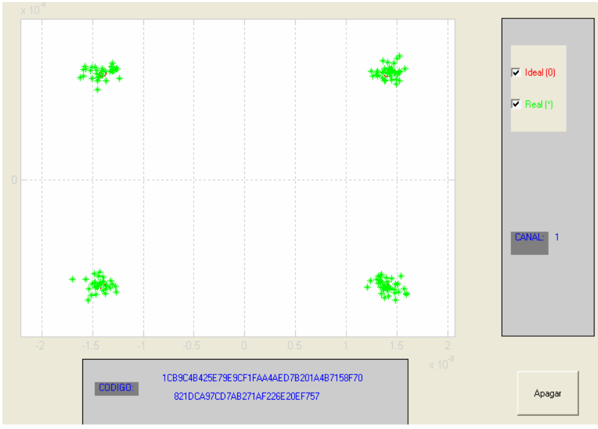

Fig. 8. 4QAM Constellation.

3.1 WDM

The WDM systems employment is more and more used due to the higher capacity transmission demand. The wavelengths of these systems have been established by the ITU-T. The students can choose the number of carriers to send and his wavelength from the 100 GHz standard grid. The program shows the spectral distribution of the different chosen carriers. [2], [4], [6]

Fig. 9. Standard 100 GHz ITU-T grid.

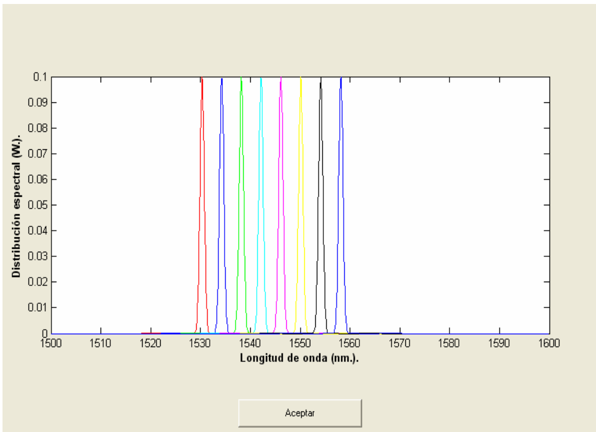

Fig. 10. 8DWDM emission.

3.2 Optical amplification

To compensate the power losses due to the signal transmission along the fibber, in the first four generations of optical systems, electronic regeneration was used. The fifth generation employs optical amplification. The simulator models a doped fibber amplifier (DFA). The needed data are the pump power, the length of doped fibber, the noise figure and the input signal power. It allows considering equalized and non equalized amplifiers. [7], [8].

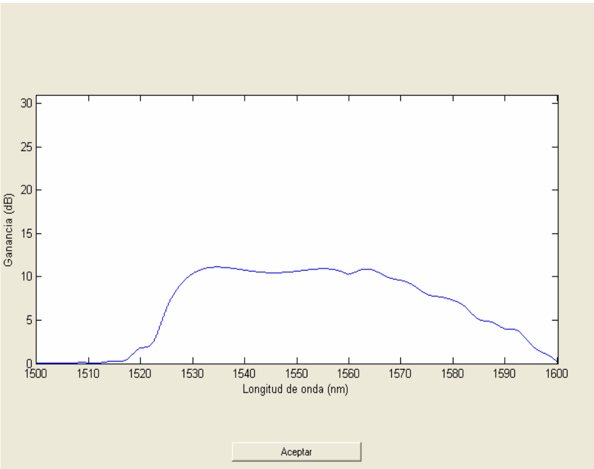

Fig. 11. Optical amplifier power response

The equalization influence of the optic amplifier can be analyzed by means of the spectrum of wavelengths at different points of the communications system.

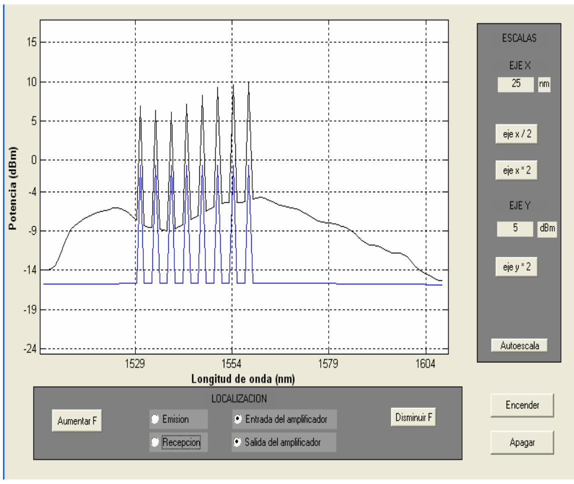

Fig. 12. Transmitted and received signals in the EDFA.

4 Results

This tool has been used for teaching the subject called Optical Communications corresponding to the degree of Telecommunication Engineering. The students have carried out practices with the different generations.

At the end of the work sessions, we carried out an opinion poll that allowed improving the simulation program. The opinions showed a good degree of satisfaction.

5 Conclusion

The work carried out let us to simulate different types of optical communications systems. The simulations give information about the behaviour of each block individually and of the whole system. The environment is friendly to the user and it facilitates the better study of the subject. The educational results obtained with their employment are satisfactory, completing the theoretical teaching received in the subjects of optical communications and signal transmission.

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