Optimization of optical filter bandwidth for the FSK demodulator in combined IM/FSK modulation formats

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Resumo **- Neste artigo reportamos o estudo e optimização de formatos de modulação ortogonais, nomeadamente IM/FSK. Estes formatos de modulação ortogonais foram propostos, recentemente, como uma solução para a introdução de cabeçalhos ópticos em tráfego IP, colocado sobre redes DWDM. Foi utilizada simulações numérica para a optimização do sistema e a variação da taxa de erros do sistema em função do ritmo de transmissão IM e FSK.**

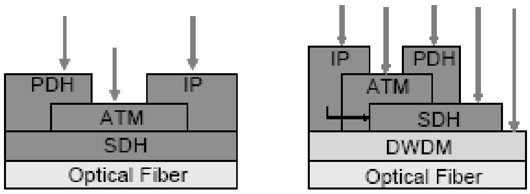
Abstract **– We report the study and optimization of orthogonal IM/FSK modulation format systems. These combined modulation formats have been proposed recently to optical labeling of high speed IP packets through DWDM networks. Numerical simulation was used to optimize the optical filter bandwidth of FSK demodulator and to obtain the variation of FSK performance with different FSK and IM bit rate.**

I. INTRODUCTION

In the last years, trigged by the internet use, the communications traffic has suffered a large increased of packet based traffic.

The network management, control and survivability in a multi-vendor, multi-operator and multi-costumer all-optical environment require the ability to measure the performance of the optical data, detecting of degradation, failure and provisioning means of failure location and isolation in order to constantly maintain the QoS (quality of service). Current DWDM (dense wavelength division multiplexing) networks are managed, protected and monitored in the digital domain, usually, through the SDH (synchronous digital hierarchy) layer, over which the ATM(asynchronous transfer mode), PDH (plesiochronous digital hierarchy) or IP (internet protocol) layers are placed, as shown in figure 1a.

The GMPLS (generalized multiprotocol label switching) protocol enables the allocation of IP packets directly over DWDM channels, since it reads the label of each packet, replaces it with a new one and at the same time performs the appropriated routing function, yielding to a significant increase of the network throughput, figure1b.



a b

Fig. 1 – Network layers.

The processes of label reading and replacing are perform at the electric domain, in each node. In order to increase the efficiency and network capacity, the AOLS (all-optical label swapping) technique has been proposed. In this technique the packet reading and routing are carried out directly in the optical domain [1]. The use of optical label swapping allows the setup of optical paths along which the payload data is routed transparently, avoiding the electronic payload processing. Several techniques for labeling of the optical signals have been proposed, such as bit serial label, optical sub-carrier multiplexed label and optical code division multiplexing [2,3]. Recently also the orthogonal modulation technique have been suggested. In this case, the label is modulated in FSK (frequency shift key) format, while the IP payload is modulated in IM (intensity modulation). The proposed method has the advantage of simplicity of the label extraction and encoding process [4-6].

We study, by numerical simulation, the influence of the FSK modulation frequency detuning and bit rate on the system performance. It was considered four different IM bit rates: 10 Gb/s, 20 Gb/s and 40 Gb/s.

II. IM/FSK MODULATION

We use a commercial photonic simulator (VPI Transmission Maker TM) to perform the optimization of the IM/FSK system. The structure of the used combined modulation scheme is shown in figure 2.

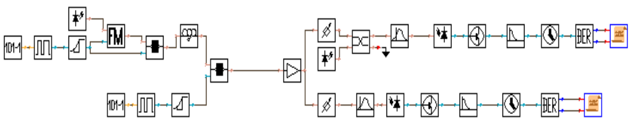


Fig. 2 – System setup.

The laser current is modulated in order to obtain FSK modulation format, in our case we use four different frequency detuning: 7.5 GHz, 10 GHz, 15 GHz and 20 GHz, centered at 1553.3 nm. We also consider four FSK bit rates: 625 Mb/s, 1.25 Gb/s, 2.5 Gb/s, 5 Gb/s. A residual intensity modulation was used to simulate non ideal modulation characteristics of the FSK modulation process. The IM modulation is imposed by a Mach-Zhender external modulator. In this study we use different bit rate for IM payload, 10 Gb/s, 20 Gb/s and 40 Gb/s. The IM signal is directed detected, after filtered through an optical filter with a bandwidth of 4 times the IM signal bit rate, centered in the signal wavelength. After conversion to the electric domain the signal is filtered by low pass Bessel filter with a -3 dB bandwidth of 0.75 of the IM signal bit rate. For the FSK signal we use a heterodyne coherent receiver. After converted to the electric domain the signal is filtered by a low pass Bessel filter with a cutoff frequency of 0.75 of the FSK signal bit rate.

III. Optimization

To obtain the optimal bandwidth of the optical filter in the FSK demodulator, for a given bit rate, we perform a sequence of optimization simulations. We verified that the detuning frequency (*df*) variation do not affect the optimum filter bandwidth. Figure 3 shows the results of this optimization process to the IM and FSK bite rates of 20 Gb/ and 2.5 Gb/s, respectively. This step is repeated to the other FSK and IM bit rates.

After the FSK receiver optimization, we verify the relation between the BER of the FSK signal and the frequency detuning for several values of bit rate. In figure 4 is represented this relationship for an IM bit rate of 20 Gb/s. As expected the BER will decrease as the FSK bit rate increases. For a given FSK bit rate smaller than the frequency detuning, the system performance is not increased by the increase of the frequency detuning

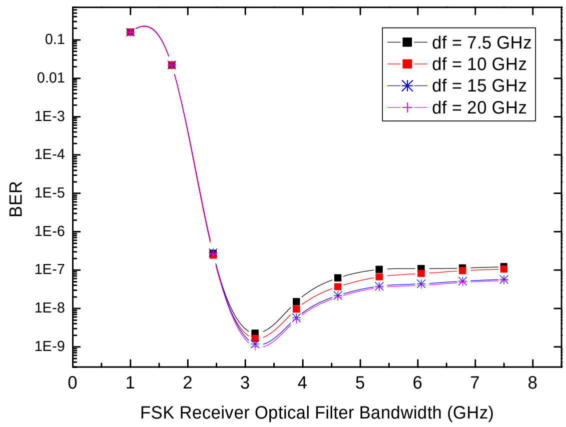


Fig. 3 – Optical filter optimization. IM=20Gb/s, FSK=2.5Gb/s

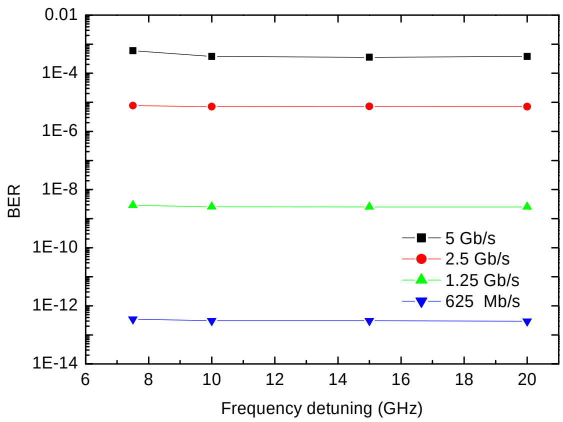


Fig. 4 – BER of the FSK signal as function of the frequency detuning.

The performance of the IM signal was obtained as function FSK bit rate and for several values of IM bit rate, figure 5. From these results we concluded that is possible to used higher FSK bit rates as the IM bit rate increase. We must refer that these results were obtained for a back-to-back configuration, it is expectable for fiber propagation a better overall performance for the 10 Gb/s bit rate.

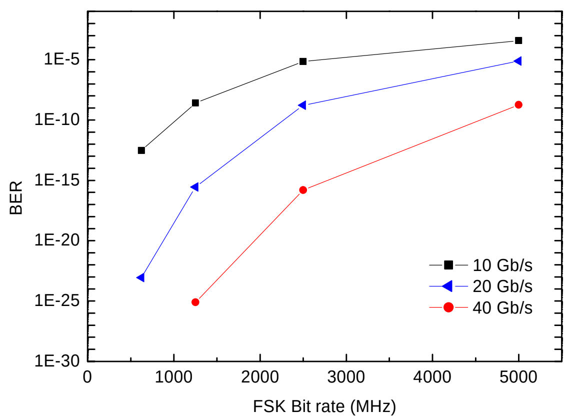


Fig. 5 – BER of the FSK signal as function of the frequency detuning.

From figure 5 we observe that to obtain a 10^{-12} BER for the IM signal we must used FSK bit rates of 625 Mb/s, 1800 Mb/s and 3700 Mb/s for the following IM bit rates 10 Gb/s, 20 Gb/s and 40 Gb/s, respectively.

IV. CONCLUSIONS

We optimize the modulation characteristics of an IM/FSK combined modulation format system. The relevance of the signal bit rate in the system performance was verified. It was also obtained the optimum value for the optical filter of the FSK heterodyne receiver.

This study is from vital importance, since this combined modulation formats have been proposed as a way to implements the AOLS, which provides an increase in the efficiency and capacity of the optical networks.

ACKNOWLEDGEMENTS

We would like to thank AdI and Siemens for the financial support given to project CONVOCO.

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