WDM Ethernet PON based on downstream narrow-FSK modulation

I. Garcés, A. López, J.J. Martínez, A. Villafranca, M.A. Losada
TOYBA Lab., I3A - University of Zaragoza, PT Walqa, Ed. 1, 22197 Cuarte (Huesca) SPAIN
{ ngarces, aliclope, jjosemar, a.villafranca, alosada } @unizar.es

Abstract *We propose and test experimentally a GbE PON architecture based on downstream narrow-FSK modulation, obtained by direct modulation of a DFB laser and upstream transmission achieved by intensity modulation of the FSK signal within a colorless user terminal.*

Introduction

Passive Optical Networks are receiving a lot of interest lately because they represent the cheapest way to achieve fibre to the home and are thought to break the bottleneck between core and access networks. In this work, we propose and evaluate a PON architecture over GbE frames based on colorless ONUs served by a single wavelength. The information downstream is inserted using narrow-Frequency Shift Keying (FSK) modulation of the carrier, obtained by directly modulating a DFB laser, which is then reused to carry the upstream data modulated in intensity by an external modulator. FSK/IM approaches have been used to transmit data in core [1] and access networks [2]. The main interest of this approach is its high spectral efficiency compared to similar schemes based on DFB direct modulation, because here the spectrum of the modulated signal is only slightly higher than the CW signal. This narrow shift allows the use of less than 25 GHz separation between wavelengths in a WDM PON approach and reduces chromatic dispersion penalties in each channel. Moreover, the narrow-FSK modulation increases the effective optical bandwidth of the signal which decreases the efficiency of non-linear effects such as Brilluoin Scattering in the downstream signal, and also the amount of Rayleigh Scattering [2], allowing to transmit higher optical powers from the OLT.

Network Architecture

The network architecture that we propose is depicted in Figure 1. It is based on a set of directly modulated lasers (DML's) each one serving 32 to 64 users and using, for example, a dynamic TDMA request/grant approach to obtain collision avoidance (as in EPON).

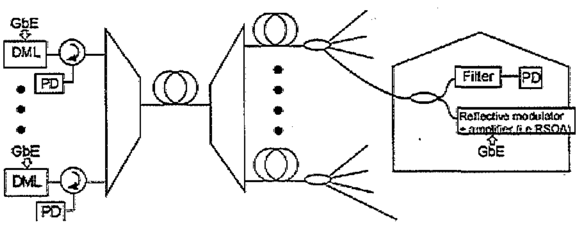

Figure 1.- Proposed PON architecture

The modulation of the lasers has to be very low, so the IM modulation of the transmitted signal is almost negligible, but the frequency of the laser is modulated by means of its own chirp. Figure 2 shows the optical spectra of an un-modulated laser and a narrow-FSK modulated laser, measured using a BOSA from Aragon Photonics. The actual optical frequency separation between '1' and '0' optical power levels depends on the modulation depth and on the adiabatic chirp characteristics of the laser [3]. In the ONU the Ethernet downstream FSK signal is demodulated by means of an a-thermal filter based on a MZDI design and then, directly detected.

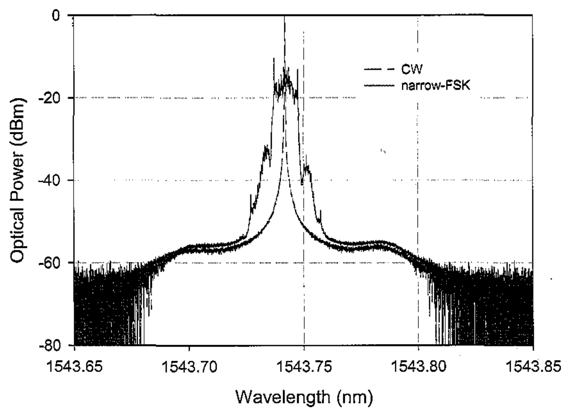

Figure 2.- Measured optical spectra of a CW DFB signal and a narrow-FSK modulated signal.

This same signal is then intensity modulated in the ONU to carry the upstream Ethernet channel, provided that the residual IM modulation of the FSK is very low. A reflective modulator such a RSOA would be the ideal device to achieve this [4] but there may be other possibilities based on other types of modulators. This approach facilitates the use of WDM to combine several channels, sharing optical fibre resources and increasing the number of ONUs that can be served from the same OLT.

Experimental

The experimental set-up used to evaluate the proposed PON architecture is shown in figure 3.

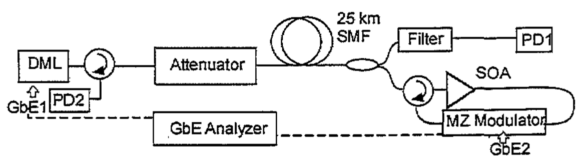

Figure 3.- Experimental set-up

A GbE analyzer (GbE Advisor, from Agilent) is used to generate and detect GbE frames simultaneously in the upstream and downstream channels. Therefore, the bit error rates (BER) presented in this paper are obtained as the number of Frame Check Sequence errors over the total number of transmitted bits. We used a 1544 nm DFB laser source emitting 10 dBm optical power with a line-width enhancement factor of 3.6 and an adiabatic chirp of 3 GHz/mW. The downstream FSK signal goes through an attenuator and 25km of optical fibre. The FSK signal is demodulated at the reception end using an a-thermal MZDI filter with 4dB insertion loss and 2.5 GHz FSR. The same signal is then amplified using a SOA with 15 dB gain and modulated using a MZM to insert the upstream data. In figure 4 the spectrum of the signal after the MZM is shown along with the GbE channel alone to ease their comparison.

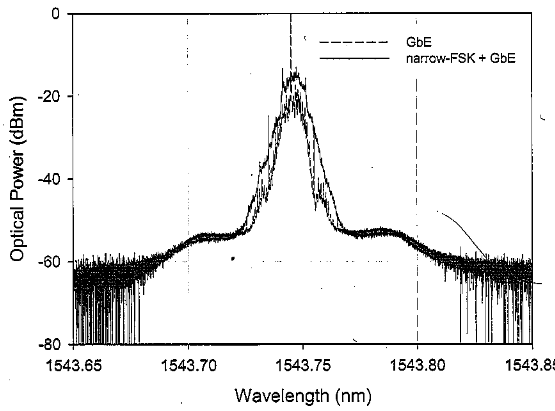

Figure 4.- Measured optical spectra of the signal after the MZM with and without narrow-FSK modulation.

The inset of Figure 5 shows the eye diagram of the narrow-FSK demodulated signal with the GbE mask test, demonstrating the quality of the demodulation after transmission. BER measurements are also presented, showing sensitivities in the range of -28 dBm, and allowing optical power budgets around 30 dB in the downstream channel.

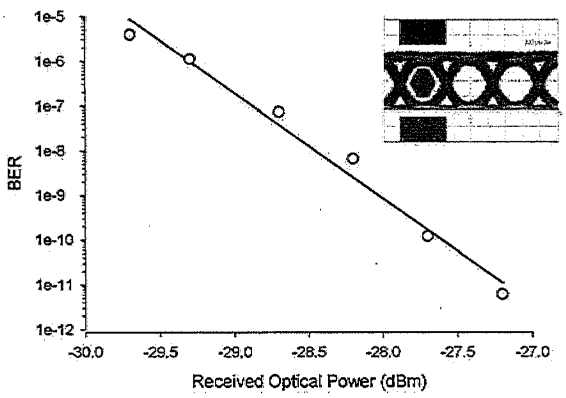

Figure 5.- BER and eye diagram of the downstream, narrow-FSK signal after demodulation.

Figure 6 shows the eye diagram of the upstream channel after transmission. Although some residual IM from the FSK channel still remains, it can be seen that the eye fits the GbE mask. BER measurements reach sensitivities close to those measured for the downstream channel. Some amplification is needed if the channel has high attenuation, as the optical power used for the upstream channel has been also attenuated in the downstream channel. Power budgets in this case are more difficult to calculate, because they depend on the attenuation of the downstream channel and on the amplifier gain. Nevertheless, when using a 15 dB gain SOA, and 21 dB loss in the downstream channel, the power budget for the upstream channel is around 22 dB for our configuration.

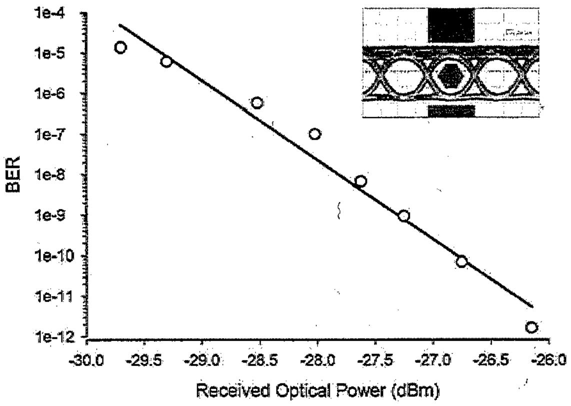

Figure 6.- BER and eye diagram of the upstream IM signal.

Conclusions

A Ethernet PON suitable for its use in WDM networks and based on the narrow-FSK modulation of the downstream channel by means of direct modulation of a DFB laser has been presented and evaluated. The upstream channel is intensity modulated using the same optical power of the downstream channel in a colorless design. GbE frames have been simultaneously transmitted over 25 km SMF achieving error-free operation.

Acknowledgement

This work was supported by the DGA, by means of project PIP108/2005 and the funds provided for the i3A Research Laboratories in Walqa Tech. Park and by Spanish MEC under project TEC2005-03060

References

1 J.J. Vegas-Olmos et al. Opt. Express, (2003), 3136
2 J. Prat et al. Phot. Technol. Lett. (2005), 702
3 R. S. Vodhanel et al. J. Lighwave Technol. (1990), 1379
4 E. Wong et al. OFC2006, paper PDP49