Modeling Optically Prefiltered AM Subcarrier Multiplexed Systems

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***Abstract*—We provide the theoretical modeling of optically prefiltered AM subcarrier multiplexed systems, taking into account the coherence of the optical source. This model provides an useful tool to calculate the crosstalk impairment that appears in the subcarrier systems with optical prefiltering. Simulation carried on using realistic parameters is also presented that validates the results from the theoretical analysis.**

I. Introduction

The Subcarrier Multiplexing (SCM) approach represents a very attractive alternative to increase the spectral efficiency of lightwave systems [1]. Novel digital transmission applications require high modulation rates (>100 Mbps) that yield wideband SCM channels. Thus, long-haul optical networks must to be used to carry those wideband SCM systems. In order to perform this, two important limitations must be pointed out in traditional SCM systems. First, the channel electronic tuning approach necessitates that the required photodiode, as well as microwave receiver bandwidth, have to be the same throughout the SCM bandwidth system, since SCM tunable receivers have to be able to select any of the SCM channels. Furthermore, another limitation is the low flexibility of the SCM network, since in order to upgrade the capacity of the system (i.e., adding more channels) the optical receivers must be replaced by others with the proper bandwidth of the new SCM system. Therefore, the bandwidth of the optical receiver limits the capacity of the SCM system.

On other hand, recent advances in optical processing technology have resulted in the feasibility of some optical components such as tunable optical filters, with expected decreasing costs in the next years. Therefore, the use of optical components in the fiber user loop will become an attractive alternative in the near future. In order to overcome the limitations imposed by electronic processing in SCM systems, optical processing is considered for tuning channels, as already proposed in other multiplexing techniques such as optical frequency division (OFDM) and code division (CDMA).

Recently, optical channel prefiltering in amplitude modulation SCM systems (AM-SCM) has been proposed [2], [3]. In this technique, the SCM channels are selected by means a tunable optical filter, prior to being directly detected at receiving photodiode, as occurs in OFDM systems [4]. The advantage of this approach is twofold. On the one hand, the translation of the signal processing to the optical domain helps to alleviate the so-called electronic bottleneck that occurs in broadband communication systems, as the increase in the number of transmitted channels poses more stringent requirements on the speed of the electronic circuits at the receiver. On the other hand, and as it will be shown later, the required bandwidth of the optical receiver is no larger that of the whole transmitted composite band, but rather, it is dictated by that of a single channel. This latter advantage results in a much more simple and therefore low cost receiver configuration and has the added value of providing the extra flexibility that traditional SCM systems lack when the network needs to be upgraded.

This paper deals with the theoretical modeling and simulation of optically prefiltered AM-SCM systems, taking into account the finite linewidth optical sources. The proposed model is aimed to calculate the crosstalk impairment in optically prefiltered SCM systems, and the influence that the source coherence has on the latter. The paper is structured as follows. In Section II, we describe the theoretical model. This model yields two different optical prefiltering techniques studied in Section III. In Section IV, we compare both optical prefiltering techniques. In Section V, we study by means simulation the previously modeled dc and RF optical prefiltering techniques, considering a realistic 155-Mbit/s subcarrier system, and we focus on some aspects that have not been taken into account in the theoretical model, such as the intermodulation effect and signal distortion arising from optical filter process. Finally, the conclusions of the study are presented in Section VI.

II. Model

Fig. 1 depicts the block diagram of an optically prefiltered SCM-IM/DD system. In the theoretical model we consider a SCM band of N subcarriers tones distributed from w_1 to w_N. The composite RF signal at the output of the electronic multiplex modulates the intensity of a laser source. Let

$$E_{in}(t) = \left[1+\sum_{i=1}^{N} m_i \cos(w_i t)\right]^{1/2} e^{jw_0 t}\xi(t) \qquad (1)$$

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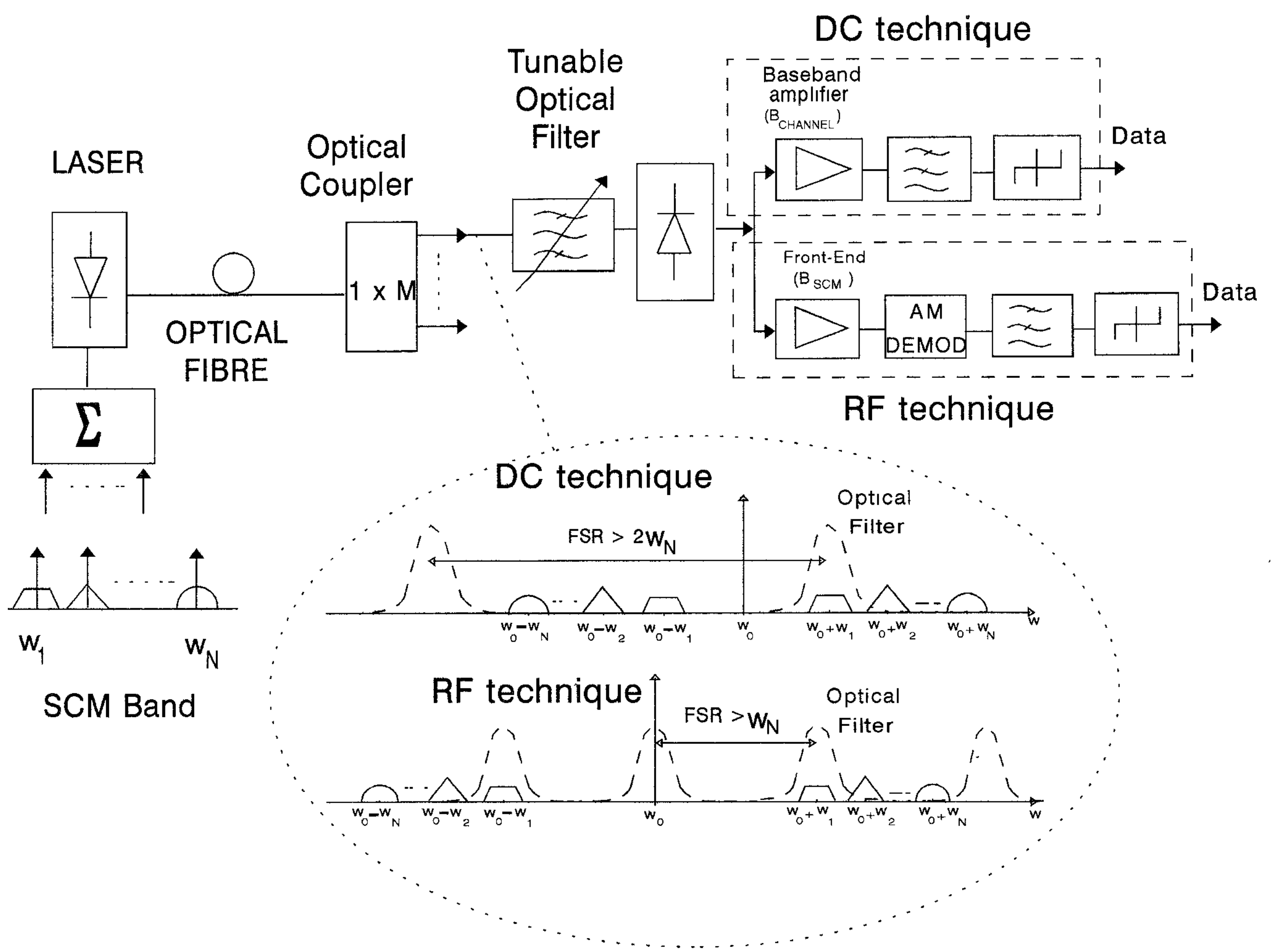

Fig. 1. Optically prefiltered AM-SCM system setup with different filtering process for the dc and RF techniques.

represent the incident electrical field on the optical filter, $\xi(t)$ being the laser source field envelope, m_i the optical modulation index of the i-channel, and w_0 corresponding to the angular frequency of the optical carrier. Note that chirp and frequency modulation effects arising from directly modulated lasers are not considered in this model. These effects may be neglected by employing laser devices with very low linewidth enhancement factor ($\alpha < 1$) such as multiple-quantum-well (MQW) laser structures [5] for which the intensity modulation efficiency is higher than the frequency modulation efficiency. In addition, the model presented below for direct modulation may be easily extended for the case of using optical external modulators. Considering for simplicity that all the channels have the same optical modulation index value ($m_i = m, \forall i$), and that this value is small enough to make the linear approximation of the square root in (1), the incident electrical field may be expressed as

$$E_{in}(t) \approx \left\{1 + \frac{m}{4}\sum_{i=1}^{N}\left[e^{j(w_0+w_i)t} + e^{j(w_0-w_i)t}\right]\right\}\xi(t.). \quad (2)$$

In this theoretical model we assume that the optical filter is a Fabry–Perot Cavity (FPC) with two mirrors of equal electric field reflectivity (r) and a cavity length L with an effective index of refraction of n_c. The transmitted field through the FPC is

$$E_{tr}(t) = (1-r^2)\sum_{n=0}^{\infty} r^{2n}\xi(t_n) \cdot \left\{e^{jw_0t_n} + \frac{m}{4}\sum_{i=1}^{N} \cdot \left[e^{j(w_0+w_i)t_n} + e^{j(w_0-w_i)t_n}\right]\right\}\xi(t) \quad (3)$$

where $t_n = t - (2n+1)T$, $T = n_cL/c$ being the transit time for light to traverse the cavity and c the free-space speed of the light.

The photodetector output current $i(t)$ is proportional to $\langle E_{tr}(t) \cdot E_{tr}^*(t)\rangle$, where the operator $\langle\cdot\rangle$ represents the photodetection time-average process. Thus, the detected photocurrent

$i(t)$ may be expressed as

$$i(t) \propto (1-r^2)^2 \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \Bigg(r^{2n} r^{2m} \Gamma[2(m-n)T] \cdot e^{jw_0(m-n)2T} \times \Bigg\{ 1 + \frac{m}{2}\left[\sum_{i=1}^{N}\cos(w_i t_n) + \sum_{j=1}^{N}\cos(w_j t_m)\right] + \frac{m^2}{8}\sum_{i=1}^{N}\sum_{j=1}^{N}[\cos(w_i t_n + w_j t_m) + \cos(w_i t_n - w_j t_m)] \Bigg\} \Bigg) \quad (4)$$

$\Gamma(\tau)$ being the normalized coherence function of the optical source $[\Gamma(0) = 1]$ defined as $\Gamma(\tau) = \langle \xi(t) \cdot \xi^*(t-\tau)\rangle$. After some mathematical manipulations [6] the photocurrent expressed in (4) may be decomposed in terms at baseband frequencies, subcarrier radiofrequencies RF (from w_1 to w_N) and different beats (sum and difference) between the subcarrier frequencies ($w_i \pm w_j$). Assuming a laser source $\Gamma(\tau)$ may be further developed as $\Gamma(\tau) = e^{-|\delta w \tau|}$ where $\delta w = 2\pi\delta f$ and $2\delta f$ is the spectral laser linewidth (FWHM) when no modulation signal is considered. Therefore, those terms of the detected photocurrent $i(t)$ may be expressed as

Baseband terms:

$$i_{DC}(t) \propto \frac{(1-r^2)^2}{1-r^4} \cdot \Bigg\{ \frac{1 - r^4 e^{-4\delta w T}}{1 + r^4 e^{-4\delta w T} - 2r^2 e^{-2\delta w T}\cos(2w_0 T)} + \frac{m}{8}\sum_{i=1}^{N} \Re[1 - r^4 e^{-4\delta w T} e^{-4jw_i T} / 1 + r^4 e^{-4\delta w T} e^{-4jw_i T} - 2r^2 e^{-2\delta w T} e^{-2jw_i T}\cos(2w_0 T)] \Bigg\}. \quad (5)$$

RF subcarrier terms:

$$i_{RF}(t) \propto (1-r^2)^2 \frac{m}{2}\sum_{i=1}^{N} \cdot \frac{|K|}{\sqrt{1 + r^8 - 2r^4\cos(2w_i T)}}\cos(w_i t) \quad (6)$$

where K is

$$K = 2 + \frac{r^2 e^{-2(\delta w \pm jw_0)T}}{1 - r^2 e^{-2(\delta w \pm jw_0)T}} + \frac{r^2 e^{-2[\delta w \pm j(w_0 \pm w_i)]T}}{1 - r^2 e^{-2[\delta w \pm j(w_0 \pm w_i)]T}}. \quad (7)$$

Beats between subcarrier frequencies (sum and difference):

$$i_b(t) \propto (1-r^2)^2 \frac{m}{8} \cdot \Bigg\{ \sum_{i=1}^{N}\sum_{j=1}^{N} \frac{|P|}{\sqrt{1 + r^8 - 2r^4\cos[2(w_i + w_j)T]}} \cdot \cos[(w_i + w_j)t] + \sum_{i=1}^{N}\sum_{j\neq i=1}^{N} \cdot \frac{|P|}{\sqrt{1 + r^8 - 2r^4\cos[2(w_i - w_j)T]}} \cdot \cos[(w_i - w_j)t] \Bigg\} \quad (8)$$

where P is

$$P = [1 - r^4 e^{-4\delta w T} e^{-4jwT}]/[1 + r^4 e^{-4\delta w T} \cdot e^{-4jwT} - 2r^2 e^{-2\delta u T} e^{-2jw_i T}\cos(2w_0 T)]. \quad (9)$$

Note that the photocurrent terms depend on T, which is the tuning parameter of the optical filter. Also, it is important to note the difference between baseband and RF photocurrent terms concerning to the dependence on the optical modulation index per channel (m^2 for dc and m for RF), since m must be smaller than the unit because of the intermodulation noise limitation [1]. Then, the amplitude of dc terms will be smaller than the amplitude of RF terms.

III. Optical Prefiltering Techniques

The information that is carried by the channels remains in both the baseband and the RF subcarrier frequencies, and depending on which one is chosen to recover the information, we can speak of two different optical prefiltering techniques. We will thus distinguish between dc and RF techniques. When the information is directly obtained from the dc photocurrent [as corresponds to baseband terms in (5)], we will speak of dc optical prefiltering technique. If the RF, photocurrent is used to obtain the information by means an AM electronic demodulator we will speak of RF optical prefiltering technique. Each technique implies a different optical receiver as well as a different filtering process as shown in Fig. 1. In the following we discuss the characteristics and differences between both techniques.

A. DC Technique

This optical prefiltering technique is based on the recovery of the information by means of the dc photocurrent as indicated by (5). Two terms may be distinguished from (5). The first one corresponds to the optical carrier (w_0) contribution, which is rejected by the optical filter as shown in Fig. 1. The second one represents the contribution of the information channels. Also, Fig. 1 shows the optical filtering process corresponding to dc technique. It may be observed that only as one sideband from of the intensity-modulated laser is selected and this imposes the condition that the free spectral range (FSR) of the FPC must verify that FSR $\geq 2w_N$ to avoid the overlapping between the SCM band and other resonances of the FPC. The selected sideband in the filtering process beats with itself during the photodetection process yielding the AM demodulated baseband information at the phododiode output. This is one of the most important advantages of the dc optical prefiltering technique due to the fact that the required bandwidth of the optical receiver is that correspond to one channel, and not that of the composite SCM band as in traditional SCM systems. This involves other advantages, since the optical receiver does not depend on the number of channels of the SCM system, i.e., the SCM system capacity may be upgraded in the future without changing the optical receivers of the users. This provides higher flexibility to the SCM network than traditional SCM systems. From Fig. 1 it can be observed the simple structure of the optical receiver using the dc optical prefiltering technique, which only requires narrow low pass band amplification and filtering prior to the decision circuit.

B. RF Technique

This optical prefiltering technique is based on the use of the RF photocurrent as indicated by (6). The RF photocurrent terms pointed out in (6) arise from the beat between the SCM channels and the optical carrier in the photodetection process. This optical prefiltering technique has been previously considered by Chen [7] for single modulation channel systems. The RF optical filtering process is shown in Fig. 1. In this figure, It may be observed that both channel sidebands arising of the intensity-modulated laser are selected as well as the optical carrier. Therefore, the FSR of the FPC must be equal to the radio frequency of the tuned subcarrier, since considering three adjacent resonances of the filter, the resonance that was in the middle selects the optical carrier, and its two adjacent resonances select the channel sidebands.

The RF optical prefiltering technique requires further electronic AM demodulation since the information is in the radiofrequency photocurrent signal. Furthermore, the bandwidth requirements as well as the structure of the optical receiver (as depicted in Fig. 1) are the same as in traditional SCM systems. Therefore, the RF optical prefiltering technique has no significant advantages over the electrical tuning used in traditional SCM systems.

IV. Comparison Between DC and RF Techniques

In this section, dc and RF optical prefiltering techniques are compared. The comparison is addressed to the points described below.

A. Structure of the Optical Receiver

As described previously, as well as shown in the inset of Fig. 1, the complexity of the optical receiver for dc technique is less than for the RF technique. The optical receiver for the dc technique only depends on the bandwidth of the channel, i.e., the bit rate, since the information is already AM demodulated at the photodiode output. Thus, for dc technique one can speak of 52, 155, 622 Mbit/s receivers, and so on, without consideration of the frequency distribution of the subcarriers in the SCM system bandwidth. However, the bandwidth of the optical receiver for the RF technique must be equal to the SCM system bandwidth. Besides, it requires an AM electronic demodulator.

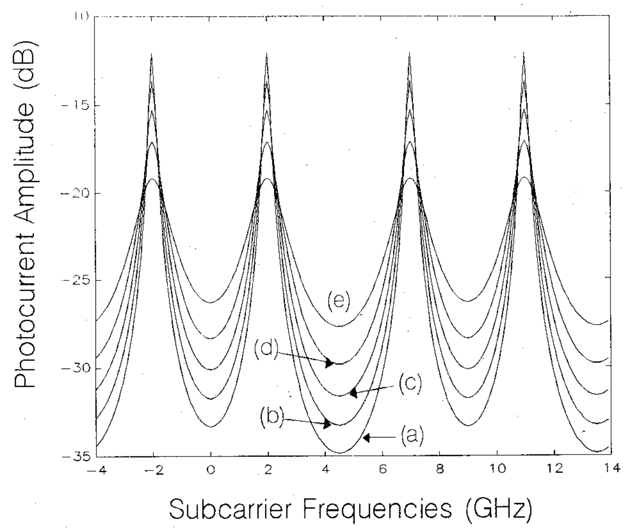

Fig. 2. Photocurrent responses for the dc technique against the subcarrier frequencies for different values of laser linewidth: (a) 0 MHz, (b) 100 MHz, (c) 250 MHz, (d) 500 MHz, and (e) 1000 MHz. The FSR of the filter is 9 GHz and the finesse is 40. A subcarrier at 2 GHz is selected.

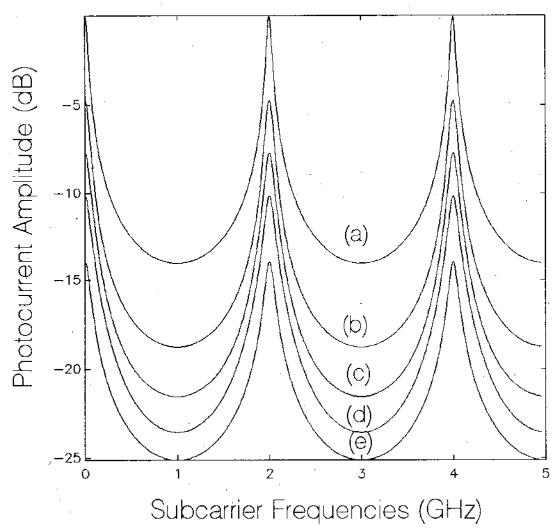

Fig. 3. Photocurrent responses for the RF technique against the subcarrier frequencies for different values of laser linewidth: (a) 0 MHz, (b) 100 MHz, (c) 250 MHz, (d) 500 MHz, and (e) 3000 MHz. The FSR of the filter is 2 GHz and the finesse is 40. A subcarrier at 2 GHz is selected.

B. Tuning Process of the SCM Channels

A fine adjustment of the cavity length of the FPC (L) using a PZT device is sufficient for tuning the channels in dc technique, whereas both fine and coarse adjustments are required in the RF technique (for instance, by means electrooptic switches), which also involves more complexity in the tuning process.

C. Effect of the Laser Linewidth on the Photocurrent Response

Figs. 2 and 3 show the dc and RF photocurrent spectrum envelope as a function of the subcarrier frequencies ($w_i/2\pi$) distributed from 2 to Ghz and for different values of laser

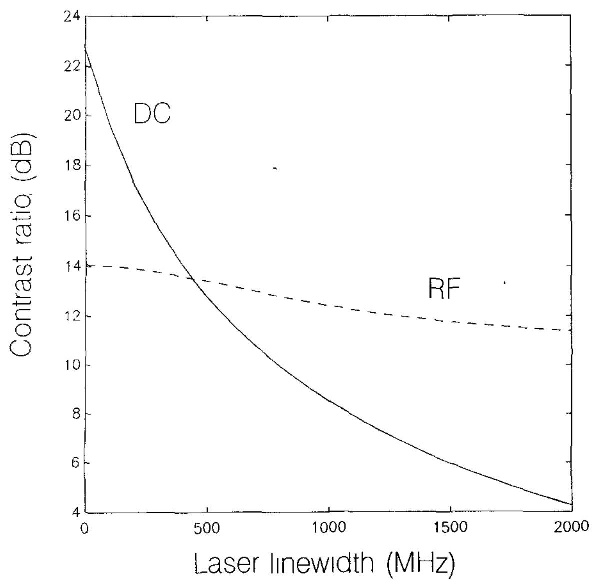

Fig. 4. Contrast ratio against the laser linewidth for the dc technique and for the RF technique.

linewidth. From Figs. 2 and 3 it may be noticed that the broadening effect of the dc and RF photocurrent responses due to the finite laser linewidth is different for both techniques. It can be seen that a higher laser linewidth produces a severe decrease in the selectivity of the dc response, while for the RF response it mainly increases the insertion losses, as well as a loss of frequency selectivity.

In order to study the effect of the laser linewidth on the photocurrent responses of both dc and RF optical prefiltering techniques, we have considered its influence on the contrast ratio. The contrast ratio of the photocurrent response defined as the maximum-to-minimum ratio is presented in Fig. 4 for dc and RF techniques. It may be clearly observed that the photocurrent contrast ratio for the dc technique is more sensitive to the finite laser linewidth effect than RF technique. For example, using an 800-MHz laser linewidth instead of a high coherence laser source (laser linewidth <100 KHz) the photocurrent contrast ratio decreases 12.5 dB for the dc technique and only 1.5 dB for the RF technique. This sharp decrease in the contrast ratio for the dc technique when the laser linewidth increases indicates that it is more sensitive to the finite laser linewidth effect than the RF technique. The later indicates that higher crosstalk levels are expected for the dc technique than for large values of laser linewidth in the RF technique.

V. Simulation

In the theoretical model presented in Section II we have done some idealistic assumptions for simplicity as subcarriers are not modulated (only tones). Furthermore, we have neglected the nonlinear terms in the square root conversion between electrical field and optical power [expressed by (2)] because the aim of the model is to calculate the crosstalk impairment [3] in optically prefiltered AM-SCM systems. In this section, a simulation study of AM-SCM systems considering 155 Mbits/s pseudorandom binary sequences as

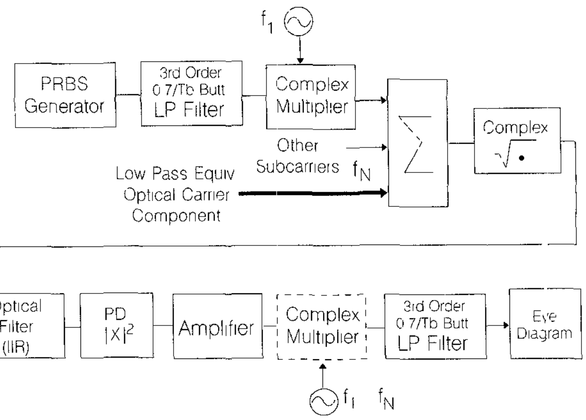

Fig. 5. Simplified block diagram of the simulated optically prefiltered AM-SCM system.

modulation signals is presented. Moreover, this study allows us to verify the theoretical analysis that has previously been carried out.

A. Simulation Model

A commercial simulation software has been used in this study [8]. Fig. 5 shows the simplified block diagram of the SCM system simulated in this study. One-hundred and fifty-five Mbit/s pseudorandom binary sequences are used as modulation signals. A square root component is used to represent the relation between optical power and electric field, i.e., a linear current-to-optical power ratio is considered. The optical filter has been modeled as an infinite impulsional response (IIR) filter with a field transfer function that matches to that of the single Fabry–Perot cavity used in the theoretical model. Both losses and dispersion effects of the optical fiber have been neglected in this study. Finally, after a low pass filter equally as previously used in transmission, the eye diagram of the received signal is analyzed.

Fig. 6 depicts the electric field spectrum at (a) the input and output of the filter for (b) the dc and (c) the RF techniques. A SCM system composed of seven 155 Mbit/s channels distributed from 2–4 GHz with an optical modulation index per channel of 0.2 has been analyzed. Both harmonics and intermodulation products at the optical filter input are shown in Fig. 6(a). These nonlinear contributions arise from the square root relation between optical power and electric field. Only higher than second-order intermodulation products fall in the subcarrier frequencies, since we have considered an SCM system of one octave band. Fig. 6(b) shows, as for the dc optical prefiltering technique, that the upper sideband of subcarrier allocated in 3 GHz (in the middle of the SCM band) is selected by means a filter with a FSR of 9 GHz.

Comparing Fig. 6(a) and (b), it may be pointed out as the ratio between the levels of the optical carrier and the tuned subcarrier has decreased after the filtering process, due to the fact that the optical carrier is rejected in the dc filtering process. However, it does not occur in the RF technique, as shown Fig. 6(c), where both upper and lower sidebands of the 3-GHz subcarrier as well as the optical carrier are selected by the filter.

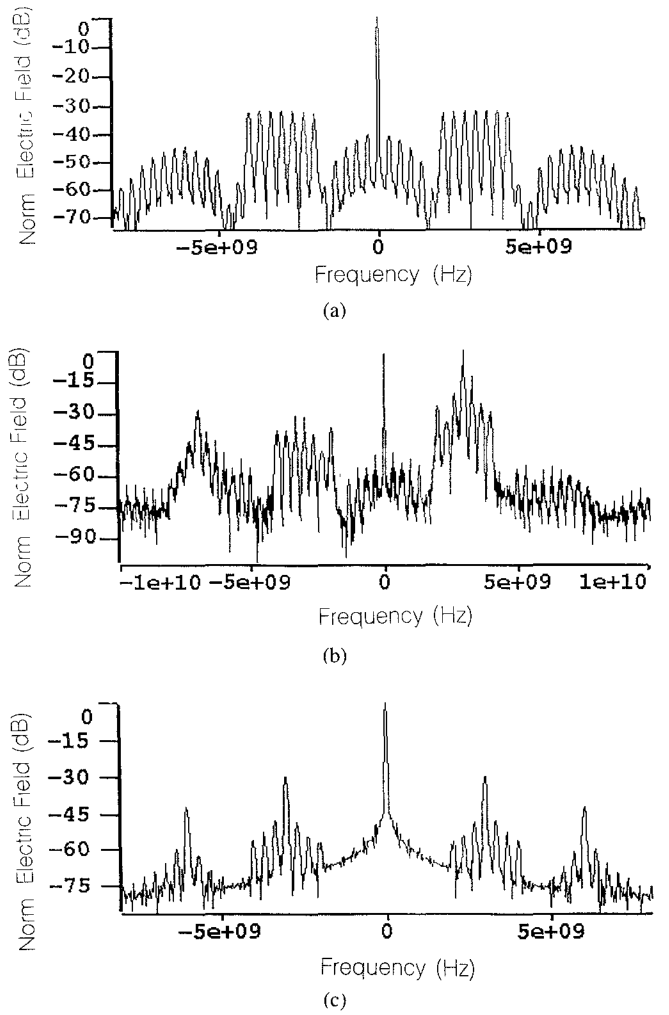

Fig. 6. Electric field spectrum (a) at the input of the optical filter, (b) at the output of the optical filter for the dc technique, and (c) at the output of the optical filter for the RF technique

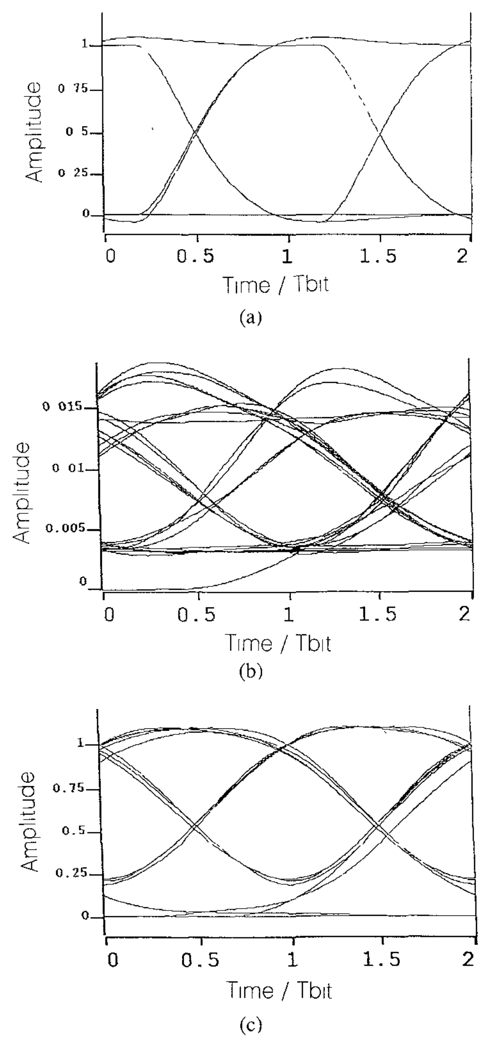

Fig. 7. Eye diagram (a) of the input signal (output of the low pass filter) and (b) of the output signal for the dc technique and (c) for the RF signal. Seven 155-Mbit/s channels with an m of 0.2, distributed from 2–4 GHz. A 0 Hz laser linewidth has been considered.

Fig. 7 shows the eye diagram of (a) the input and the output digital signals for (b) the dc and (c) for the RF techniques. In Fig. 7(b) may be observed the dramatic closure of the eye diagram due to the optical carrier has not been selected in the filtering process. However, for the RF technique only a slightly closure of the eye diagram is obtained, as shown in Fig. 7(c).

B. Study of the Nonlinear Phenomena in the Filtering Process

The nonsymmetric eye diagrams obtained from the output signals (especially for the dc technique) indicate that a nonlinear phenomena has occurred during the optical filtering process. The latter arises from the intermodulation products that fall in the selected subcarrier. To quantify this nonlinear phenomena, which has not been considered in the theoretical model, we have compared the eye diagram obtained for different values of the optical modulation index per channel (m) when the square root component is and is not used in the simulation block diagram. Fig. 8 shows the results of the filtering nonlinear effects factor (FNF) against the optical modulation index per channel. The FNF is defined as $20\log(A_L/A_{SR})$, where A_L and A_{SR} are the eye diagram apertures obtained when the linear approximation of the theoretical model and when the square root relation are considered, respectively. It may be observed that the linear relation approximates good enough the square root relation up to m of 0.3, giving a FNF of 1 dB and 0.3 dB for the RF and the dc techniques, respectively. If higher values of m were used in the SCM system, which is not common due to the high intermodulation noise that arises from the nonlinear relation between the current and the optical power, the nonlinear effect of the optical prefiltering should be take into account for the RF technique only, since for the dc technique the FNF still is less than 1 dB.

C. Linear Filtering Effects

As occurs in optical prefiltering in WDM systems [9], the nonflat passband response of the optical filter impairs the tuned subcarrier signal that passes through it [2]. This signal distortion due to linear filtering effects will reduce the aperture of the eye diagram. A simulation-based study has

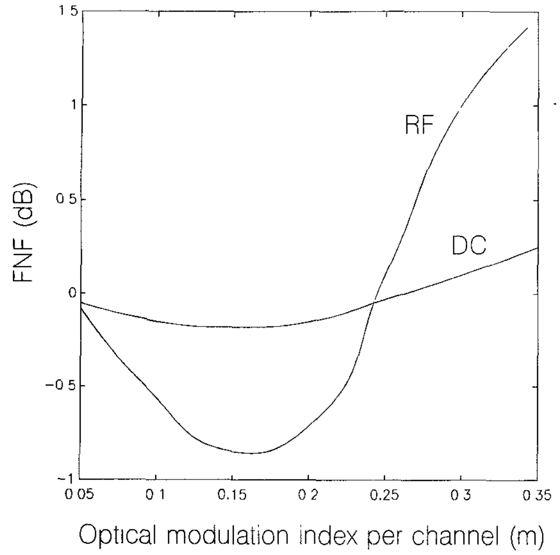

Fig. 8. Nonlinear filtering effects factor against m for both optical prefiltering techniques.

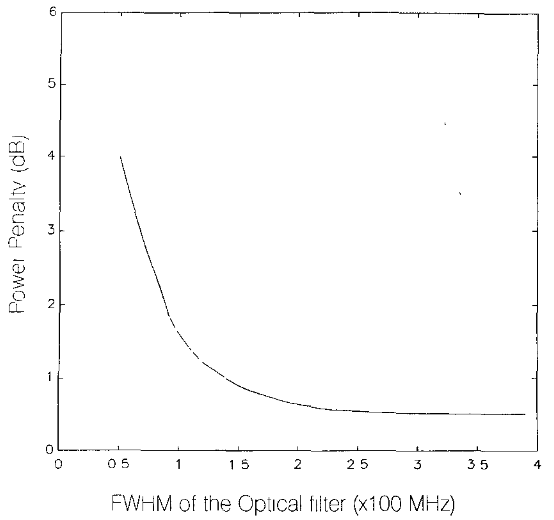

Fig. 9. Power penalty versus the FWHM (−3 dB bandwidth) of the optical filter for the dc technique.

been carried out to investigate the linear filtering effects in optically prefiltered SCM systems. Fig. 9 depicts the power penalty against the FWHM (−3 dB bandwidth) of the optical filter when only one 155-Mbit/s subcarrier is considered in the 2–4 GHz simulated SCM system for the dc technique. The power penalty has been calculated as $20 \log (A_{id}/A_m)$, where A_{id} and A_m correspond to the eye diagram aperture when an ideal filter (flat passband frequency response filter) and when single cavity Fabry–Perot filter with a FSR of 9 GHz is used, respectively. It may be observed that a sharply increases of the power penalty is obtained when the FWHM decreases from 150 MHz, which yields to an optical filter finesse of 60. Obviously, this result is slightly affected by the cutoff frequency of the electric low pass filters ($0.7/T_{bit}$) used this simulation study, as shown in Fig. 5. However, since the parameters considered in this simulation study are quite realistic, this results may give a good estimation about the signal distortion due to the filtering effects.

VI. Summary and Conclusion

We have theoretically modeled optically prefiltered AM-SCM systems considering the effect of finite laser linewidth on the photocurrent response. The model enables to calculate the crosstalk that appears due to undesired channels in the SCM band. Two different optical prefiltering techniques have been analyzed, depending on the filtering process of the selected channel. The information may be recovered from the baseband (for the dc technique) as well as from the radiofrequency (for the RF technique) photocurrent. However, the dc technique is much more attractive than the RF technique because the required bandwidth of photodiode and receiver's front-end is lower than for traditional SCM systems, since in optical prefiltering the required bandwidth of the optical receiver is the channel bandwidth only, compared to the SCM system bandwidth for traditional SCM systems. In addition, the upgradability and flexibility of the SCM network are improved. The effect of the laser linewidth on the contrast ratio of the photocurrent response for both optical prefiltering techniques is different, being the dc technique being more sensitive than the RF technique to this parameter of the laser. Thus, higher coherent laser source should be employed for the dc technique than for the RF technique.

We have validated the analysis of the optical prefiltering approach by means simulation using realistic high-speed pseudorandom binary data. In the simulation study we have analyzed some intrinsic impairments that arise from the optical prefiltering, such as the linear and nonlinear effects of the filtering process. The power penalty due to the linear filtering effect depending on the FWHM of a single-cavity Fabry–Perot filter with FSR of 9 GHz has been calculated. The nonlinear effect due to the optical prefiltering may be neglected for the common optical modulation index per channel values often used in SCM systems. So, the later not imposes any limitation on the system performance since when high values of m are used the intermodulation noise from the nonlinear current-optical power relation of laser is more significant than that effect arising from the nonlinear phenomena of the optical prefiltering.

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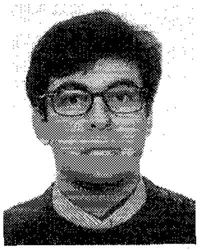
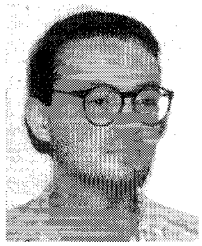


Javier Marti (S'89–M'93) was born in Gandia, Spain, on December 10, 1966. He received the Ingeniero Tecnico de Telecomunicacion and the Ingeniero de Telecomunicacion degrees in 1988 and 1991 from the Universidad Politecnica de Catalunya, and the Doctor Ingeniero de Telecomunicacion degree (Ph.D.) in 1994 from the Universidad Politecnica de Valencia, Spain.

During 1989 and 1990, he was an Assistant Lecturer at the Escuela Universitaria de Vilanova. He joined the Departamento de Comunicacions at the Universidad Politecnica de Valencia in 1991, working in the Optical Communications and Photonic Engineering Group. From 1991–1994, he was a Lecturer at the Telecommunication Engineering Faculty and he became an Associate Professor in 1995. During 1994, he was a Research Visiting Fellow at the Electronics Laboratories of the University of Kent, England, where he worked in the Optical Communications Group for three months. He has published more than 30 papers and conference contributions in the fields of OFDM and SCM lightwave systems, optical processing of microwave signals, and mobile and satellite communication systems. His current interest include optical processing of microwave and millimeter-wave signals, fiber to radio systems, microwave photonics and broadband optical communication systems.

Dr. Marti was the recipient of the Doctorate Prize of the Telecommunication Engineer Association of Spain for his Ph.D. dissertation on optical prefiltering in SCM systems.



José Capmany (S'89–M'92) was born in Madrid, Spain, on December 15, 1962. He received the Ingeniero de Telecomunicación degree in 1987 and the Doctor Ingeniero de Telecomunicación (Ph.D.) degree in 1991, both from the Universidad Politécnica de Madrid (UPM).

During 1989, he was a Visiting Student at the University College London, Department of Electronic and Electrical Engineering, where he was engaged in research on the effect of dispersion on single-mode fiber-optic encoding-decoding systems for optical CDMA. He joined the Departamento de Tecnología Fotónica at UPM in 1988 as a Research Assistant. In 1991, he became an Associate Professor of the Departamento de Comunicaciones at the Universidad Politécnica de Valencia (UPV), where he has been the Vice-Dean of the Telecommunications Engineering Faculty and Head of the Optical Communications and Photonics Engineering Group. During 1993, he was a Visiting Research Fellow for a six-month sabbatical period at the Optoelectronics Research Centre, University of Southampton, England, where he worked on dispersion compensation using fiber gratings. He has published more than 70 papers and conference contributions in the fields of fiber-optic delay line filters, fiber resonators, pulse propagation in fibers, optical CDMA systems, optical bistability in nonlinear resonators, fiber-optic sensors, WDM and SCM optical fiber communications, and microwave photonics. He has acted as a technical reviewer for several journals in the fields of electronics, optoelectronics, and optical communications.

Dr. Capmany has acted as Guest Editor for a Special Issue of the *Journal of Fiber & Integrated Optics* dedicated to "Fiber Resonators," and he is currently a member of its Executive Board. He was the recipient of the Doctorate Prize of the Universidad Politécnica de Madrid in 1992.