HIGH TUNING SPEED OPTICAL RECEIVER FRONT-END FOR PACKET-SWITCHED WDM NETWORKS

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ABSTRACT

In this work two distinct optical receiver conjurations are investigated for use in the downstream direction of ATM PON networks based on wavelength division multiplexing (WDM). The goal is to overcome the slow tuning speed of optical filters, achieving channel selection in the nanosecond time frame and allowing the implementation of an efficient ATM/WDM protocol.

INTRODUCTION

In principle, the bandwidth in optical communication systems can exceed several THz because of a large carrier frequency associated with the optical carrier, In practice, however, the bit rate is often limited to 10 Gbps or less because of the limitations imposed by fiber dispersion, fiber nonlinearity and the speed of the electronic components. The transmission of multiple optical channels over the same fiber provides a simple way of making use of the unprecedented capacity offered by optics (1). In particular, the wavelength division multiplexing (WDM) technique involves the transmission of multiple channels on the same optical fiber, where each channel is associated with one optical carrier, The system designer must take account the proper separation of the modulated carriers to prevent the crosstalk at the frequency domain and at the receiver the channels must demodulated, Selection of the desired channel is generally achieved through an optical filter or a diffraction grating.

The practical implementation of these systems requires, in principle, the development of tunable transmitters and receivers. In particular, in applications employing packet-switched "broadcast-and-select" networks, such as the downstream direction of the ATM-PON (Asynchronous Transfer Mode over a Passive Optical Network) architecture (2-3), fast tuning is absolutely crucial (4-5). Due to the possibility of wavelength reuse among the network nodes, the tuning range for the optical sources do not need to be large, Devices already demonstrated in the literature (6) will satisfy the needs of WDM networks.

In contrast, the performance requirements on the optical receivers are much more stringent. Each optical receiver must be able to cover the whole wavelength band of interest. Also, the tunability process between two arbitrary channels must occur in a time frame smaller than the necessary for transmission of a single information packet. This last requirement (5) allows the overhead minimization of medium access protocol (MAC), which controls the traffic and switching of the information packets.

In circuit-switched WDM networks, optical tuning at the receiver side is usually performed by means of Fabry-Perot and/or acusto-optical filters, employing some kind of feedback scheme to assure that the device is really tuned to the desired wavelength.

Unfortunately, this feedback process is slow, leading to tuning speeds of the order of microseconds or more. Although very specific WDM HIPPI packet-switched networks have already been successfully implemented using optical filters (7), it is clear that the tuning speed for these devices is very slow in comparison to the time needed to transmit an ATM cell at gigabit rates in downstream direction.

With the goal of overcoming these difficulties, this paper revisits an optical receiver topology based on non-tunable wavelength demultiplexing and electronic switching, A, novel receiver configuration is proposed to avoid the high insertion loss observed in previous investigations (8-10). Also, for the first time in the literature the design aims at operation well above one Gbps.

IMPLEMENTED CONFIGURATIONS AND RESULTS

Fig. 1 shows the schematic of the first implemented configuration for the integrated optoelectronic receiver (FE1). It is composed of a fixed frequency WDM demultiplexer, an array of photodetectors, an array of FETs acting as on/off switches and a common transimpedance amplifier. Proper setting of the gate control voltages of the FET switches will allow only the desired WDM channel to reach the output amplifier. The front-ends (circuitry enclosed by the dashed lines of figures 1 and 5) were designed by using HP-MDS software and implemented using AMS (Alenia - Marconi Systems) foundry's 0.5 µm GaAs MESFET technology. This first configuration employs basically the same topology as suggested by Yu *et al.* (10). However, it suffers from a high insertion loss due to its "passive" switching circuitry, which, in our case, it consists of three FETs of 300 µm gate width connected in series-shunt-series fashion.

As an alternative, this work proposes a novel configuration for the integrated optoelectronic receiver, as shown schematically in Fig.2 (FE2), Now each channel has its own transimpedance pre-amplifier and a FET switching circuit. Essentially, we expect to achieve a lower noise level and higher sensitivity at the receiver, what would certainly alleviate the optical power levels requirements at the optical transmitter, simplifying the implementation of machine and/or board level optical interconnection schemes, Specifically, noise measurement and simulation agreement demonstrated 1 dB decrease in noise figure, as shown in Fig.6. Simulations indicate that at the frequency of 2 GHz the average equivalent noise current for the first proposed topology is equal to 12 $pA/Hz^{1/2}$, being reduced to 9 $pA/Hz^{1/2}$ in the case of the second front-end topology. This novel configuration reduces the average noise at the expense of power consumption, increased circuit complexity and chip area which goes from 2.27 mm^2 up to about 4.49 mm^2. It is believed that this trade-off can be satisfactory in high-performance applications.

Very similar results were expected for both circuits regarding bandwidth and microwave gain. Due to improved amplifier design both configurations were able to achieve much larger bandwidth, around 2.5 GHz, as demonstrated in Figg.3-4, almost an order of magnitude increase over Yu *et al,* (10). Fig.5 shows the channel extinction ratio, that is the difference in the output response between the on/off switch control voltages, Fig.6 shows the OFF/ON switching performance of FE1 for an 1 GHz input signal. Fig.7 shows the switching performance of FE1 for an 1 GHz input signal and an 8 MHz switch control signal. Fig.8 presents the switching performance of FE2 for an 1 GHz input signal and an 30 MHz switch control signal with a large duty cicle. Compared to the usual photodetector-filter arrangement, the configuration above offers an measured electronic switching time of the order of hundreds of picosecond, a four-order of magnitude improvement compared to Taranenko *et al.* (7). Experimental results show longer switching times essentially due to the output AC coupling of the test set arrangement.

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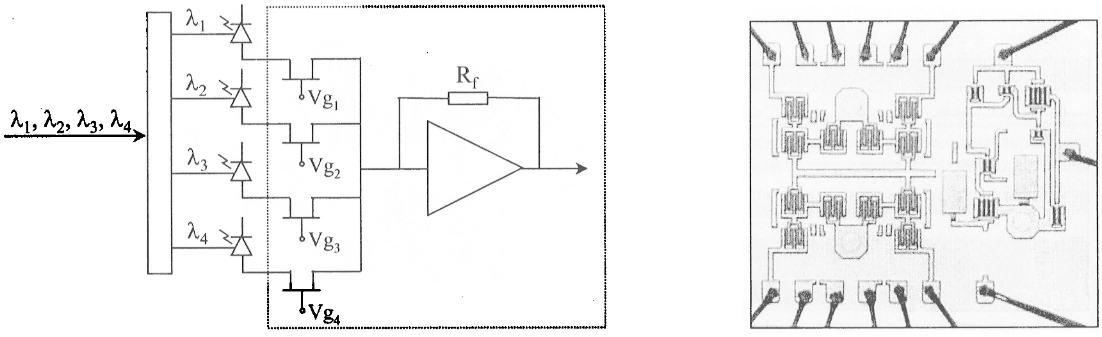

Fig. 1: First proposed configuration for integrated optoelectronic receiver (FE1).

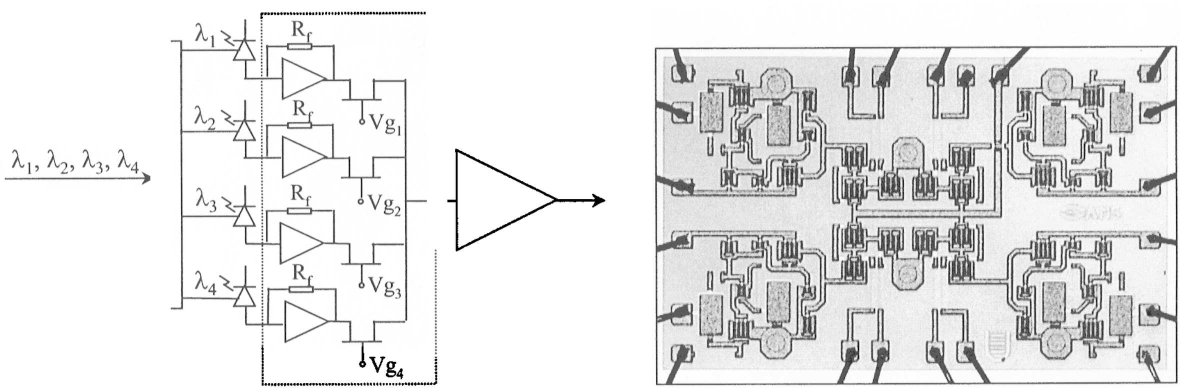

Fig. 2: Second proposed configuration for the integrated optoelectronic receiver (FEZ). .

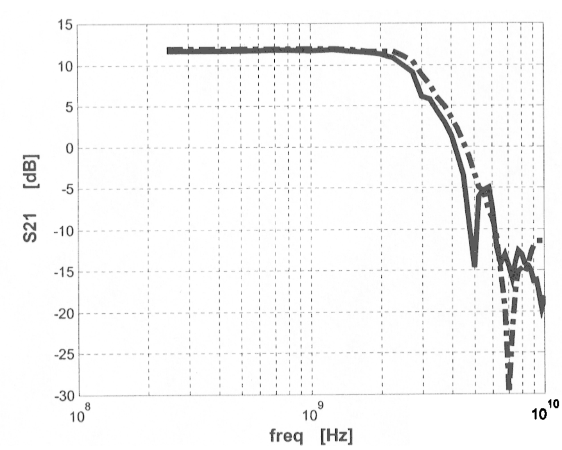

Fig.3. S21 frequency response (FE1 dashed line, FE2 continuous line)

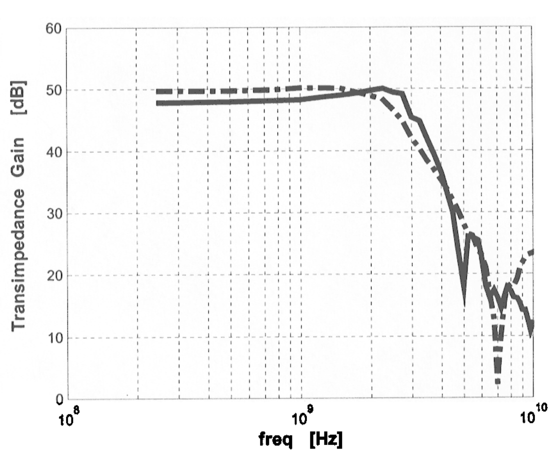

Fig.4. Transimpedance gain (FE1 dashed line, FE2 continuous line).

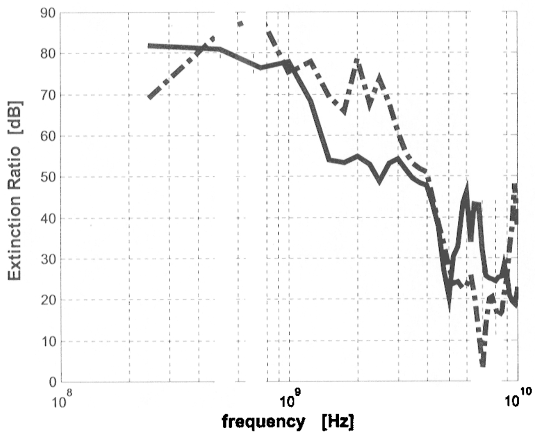

Fig.5. Extinction ratio (FE1 dashed line, FE2 continuous line).

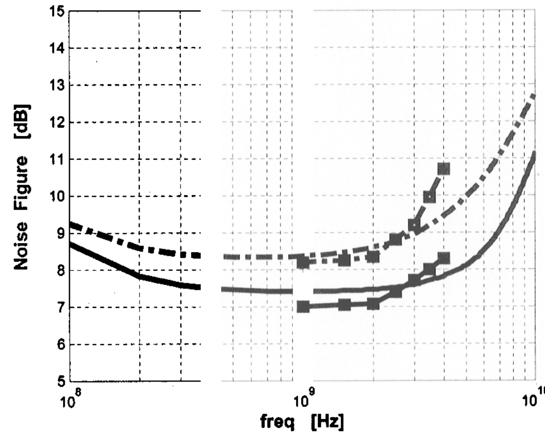

Fig.6. Noise figure measurements (boxed) and simulations (FE1 dashed line, FE2 continuous line).

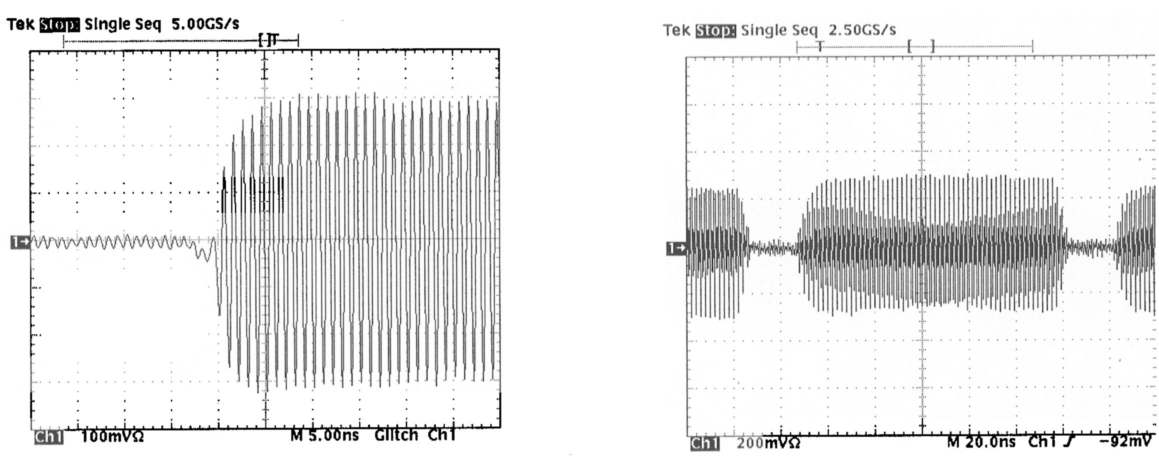

Fig.7. Switching performance of FE1 for an 1 GHz input signal.

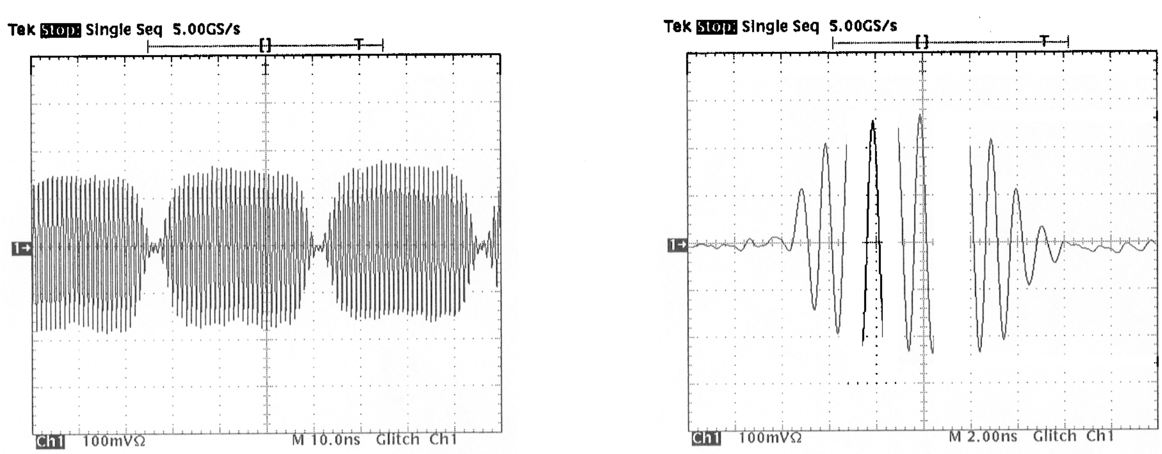

Fig.8. Switching performance of FE2 for an 1 GHz input signal.