VHDL-AMS Simulation Of An Optical Transmitter/Receiver Channel

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ABSTRACT: A system on chip (SoC) is composed of a large number of intellectual property (IP) blocks on the same silicon. However, as the number of IP blocks on a single chip and their performance continue to increase, a shift from those classic interconnections to optical ones becomes mandatory. This article presents an OCDMA architecture on-chip. In this proposal, the VCSEL diode and the photodiode communication is implemented using VHDL_AMS language.

Keywords: OCDMA, Noc, Diode Vcsel, Photodiode, VHDL_AMS

1 INTRODUCTION

THE development of integrated circuit technology and the ever-increasing performance of electronic systems greatly augment the complexity of integrated on-chip systems. In addition, the communication within the integrated data exchange and control treatments circuits has grown significantly in recent years. However, problems such as rate limiting, energy consumption, signal integrity, signal latency, and global synchronization may put an end to the development of systems on-chip. Communications between functional blocks of a system on-chip are up today performed by bus. The continuous increase in rates, led to project architectures from the telecommunications on integrated circuits, thus giving birth to the concept of NoC. Indeed, a network on chip (NoC) is an approach of the subsystem design communication between IP cores (Intellectual properties) in a System-on-Chip (SoC).

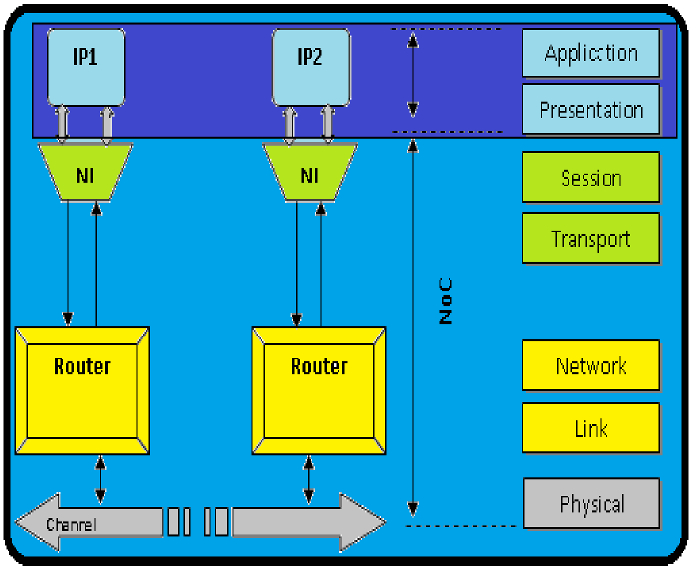

***Fig. 1**. OSI Model in NoC Magnetization*

A new paradigm for network on chip, drifted from computer communication networks based on the classical OSI communi-cation layers model, reduced to the integrated system (NoC).

The network on chip shown in Figure 1, consists of two essential elements: routers and network interfaces (NI). In fact, routers transmit data packets from one NI to other. The network interface (NI) are responsible for the packetization/disassembly for implementing connections and services, also provide a standard interface such as AXI, OCP and VCI for independence of intellectual properties (IPs) from the network on chip (NoC). The NoCs must provide scalability and flexibility of the architecture. The interconnection network plays an important role in achieving high performance, scalability, energy efficiency and fault tolerance in a NoC system [8]. Performances broadband data transfer on NoC are characterized by the following parameters:

- Quality of Service (QoS): Minimize the latency time which characterizes the information transfer. Ensure continuous availability of a physical link between the transmitter and the receiver (the contention), to ensure maximum throughput of the communication network.
- Scalability: An interconnection network is called "scalable" if it increases the number of resources which are connected intrinsically without changing its basic architecture [3]. In addition, the maximum throughput on each link must remain constant, so each new resource has the same flow.
- Simplicity: The simplicity of the NoC (characterized by the number of hardware resources required for its implementation) usually ensures better performance in terms of latency and bandwidth.

In 2001 ITRS "International Technology Roadmap for Semiconductors" [7] predicted that since 2010, SoCs work with clock frequencies of the order of 10GHz. New applications constantly pushed the boundaries, conventional metal interconnects and electronic routers gradually become a performance bottleneck due to the limited International Journal of Technology Enhancements and Emerging Engineering Research,bandwidth, large area, high energy consumption, and crosstalk noise [3]. A multiprocessor system on chip (MPSoC) using multiple processors, is used by platforms that contain elements of heterogeneous treatment with specific features justify the need to provide optical NoCs. Research has been done on integrated optical waveguides and devices comprising an optical network on chip (ONoC) [1]-[6], suggesting these as solutions to meet the demands of system on chip (SoC) new generations. Thus, the integration of optical interconnects reduces the stresses on the global metal interconnections, latency, grows the speed limits, reduces energy consumption and ensures the integrity of the transmitted signal The main objective of this work is to study the feasibility of optical interconnection network integrity based on CDMA access technique. After an introduction, we will propose in the second part, a Noc global architecture based on CDMA access technique. Then we will focus our simulations only on the behavior of photodiode (receiver) and VECSEL diode (transmitter).

2 NOC OPTICAL NETWORK BASED OCDMA

Network parameters such as throughput, latency and reliabil-ity have an influence on the choice of topology. To intercon-nect the IPs between them, we propose a NoC architecture based on optical CDMA, including its topology. The purpose of this topology is to have a compromise between perfor-mance, cost and reliability. Different from other optical NoCs, CDMA-ONoC allows transmission and reception in parallel of payload packets and control on the same optical network. This saves the cost of fabricating NoCs. Thus, the topology of our network can form a powerful multiprocessor system such as MPSoC without performance degradation.

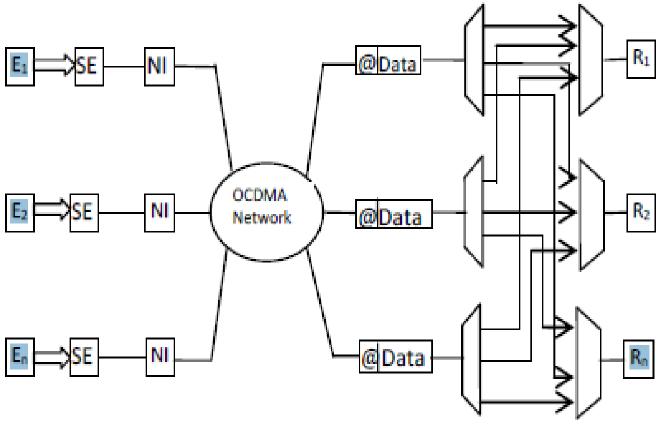

Fig. 2. *Optical network based OCDMA*
Figure 2 *shows the global proposed architecture based on optical CDMA access technique*

2.1 Transmission Section

OCDMA access technology processes and transmits data serially in the optical interconnection network. Indeed, the CDMA is based on spread spectrum technique, so, it replace each bit ‘1’ with a m-sequence code bit 'chips' and every bit '0' with the complementary sequence. In our work we propose the transmitter party allowing a number of 256 initiators and 256 targets as the maximum ca-pacity system. Therefore, an address field in the transmitted packet size of 8 bits

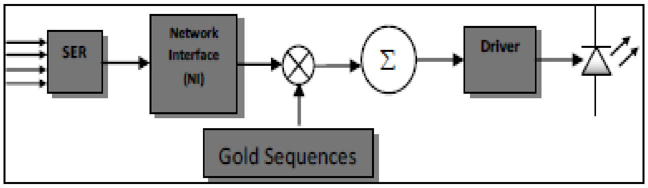

Fig. 3. *One emitter chain*

The transmitter structure (Figure 3) is composed of a serializer (SER), which frequency is N-times the N-bits Gold Sequences one, Network Interface (NI), a control circuit and a VCSEL lasers sources. The VCSEL diode current range is typically 0.5mA to 1.5mA with a maximum transmit power of about 2mW. This imposes constraints on which current the driver should provide to the VCSEL diode.

2.2 Optical Channel

Wireless optical links transmit an optical intensity modulated in response to an input laser diode electrical current signal. Generally the optical channels are optimal while employing intensity modulation and direct detection. Alignment between transmitter and receiver make a directed LOS links do not suf-fer from multipath dispersion [12]. The photodiode perform direct detection of the incident optical signal which produces an output electrical current. Theoretically, the optical channel modeled by (1)
Where *r* is the photodiode sensitivity (*r* = 0.6 mA/mW), *h(t)* is the channel response, *I(t)* is the optical output VCSEL intensi-ty, and *n(t)* is the additive noise approximated as being Gauss-ian distributed. The VCSEL diode response from *x(t)* to *I(t)* in Figure 4 can be modeled as *I(t)=G.x(t)*, where *G* is the optical gain of the laser diode.

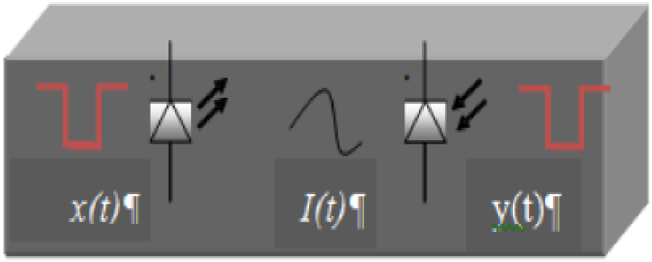

Fig. 4. *Optic transmitter/receiver in non-reflective environment*

Transmitter/receiver chain model
In this work, it is assumed that the channel is nondistorting. Consequently, the received signal *y(t)* can be modeled as *y(t)=x(t) + n(t)*

2.3 Receiver Section

The clock recovery for receiver synchronization signal has not been taken into account.

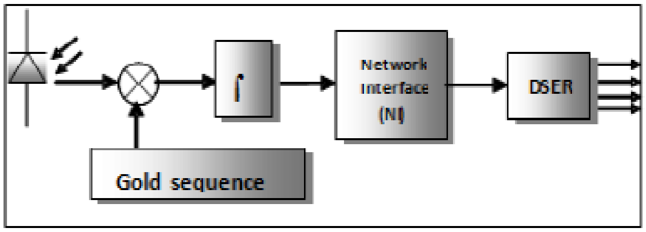

Fig. 5. *One receiver chain*

Figure 5 shows the receiver block diagram. It is composed of a photodi-ode, a decision circuit which restores the digital signal, de-spread spec-trum related to GOLD code generator. Finally, a de-serializer reforms serial bits word in parallel. The photodiode generates a current signal, thus a device convert it into a voltage to be processed by the rest of the circuit. It is imperative to insert a DLL (Delay Locked Loop) to ensure synchronization between the input signal and the GOLD codes generated, to ensure that, the received code and the local code are in phase. The received signal is multiplied by the same code sequence. If the local code sequence is correlated with the code in the intermixed signal received, then the received signal is de-spread while the noise is spread and its power decrease.

3 SIMULATION AND RESULTS

The Simplorer simulator supports interfacing between languages and software such as VHDL-AMS. Moreover, Simplorer uses a proprietary language allows it to use a primitive library. Its interface offerts a lot of flexibility to designer, for drawing and writing the associated models. The user can easily highlight the different blocks of its model and incorporate direct simulation results [9]. We opted for Simplorer because it gave us satisfaction for our work. In this paper we will use VHDL-AMS to simulate the optical wireless link between the transmitter and receiver, placed inside a non reflective environment, as depicted in Figure 4. We intend that such our optical CDMA schemes may be advantageous for high-rate short-distance optical communication.

3.1 Laser Source (VCSEL)

We proposed a simple behavioral model, which had the function to return the optical power according to the current signal input.
(2) The optical signal output by a laser diode shows fluctua-tions in amplitude and frequency, even if the laser is biased with a constant current. The two basic mechanisms that con-tribute to the noise generation are the spontaneous emission and electron-hole recombination. This defines the Relative Intensity Noise (RIN) as the ratio between the optical power spectral density fluctuations and the square of optical average power. The RIN power (PRIN) depends on the values of the random sources as input of the diode

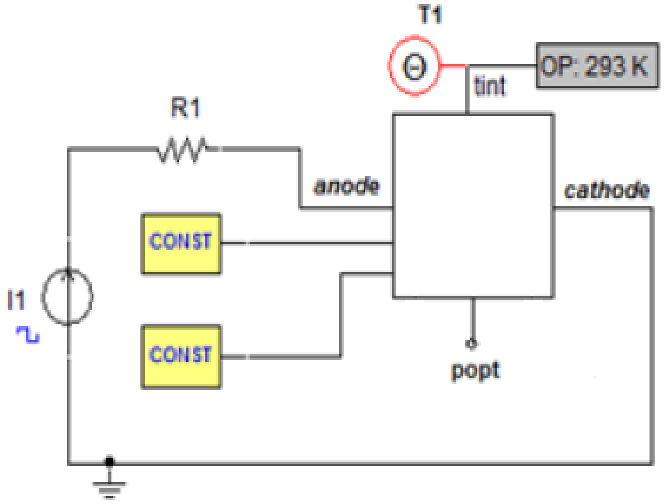

Fig. 6. *Diode VCSEL Simplorer Schematic*

Noise sources were extracted from the model and brought outside because it uses a single source of white Gaussian noise applied to noise RIN. Corresponding noise quantities are “CONST” sources. Relative Intensity Noise is superimposed on the output optical power Simplorer offers the possibility of using synchronized random generators provided by the VHDL-AMS simulator kernel. The two key parameters for simulate the pulse mode is the pulse time transition and its frequency. The frequency will affect the average power dissipated in a period, while the pulse time transition is compared to the time taken by the component to be locally heated. Beside the CDMA, each bit time is subdivided into very short chips time sequence, the vcsel diode assumed not heated.

In Figures 7 and 8 we depicted the exciting current effect of the diode, on the output optical power, for different frequencies. According to equation (2), higher frequencies deteriorates the optical power, this is what we see in the following figures

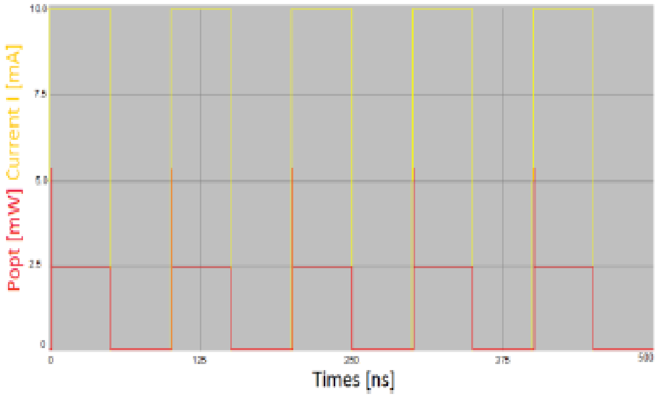

Fig. 7. *Popt for source current frequency 10MHz Low frequencies noise has no effect on the optical power*

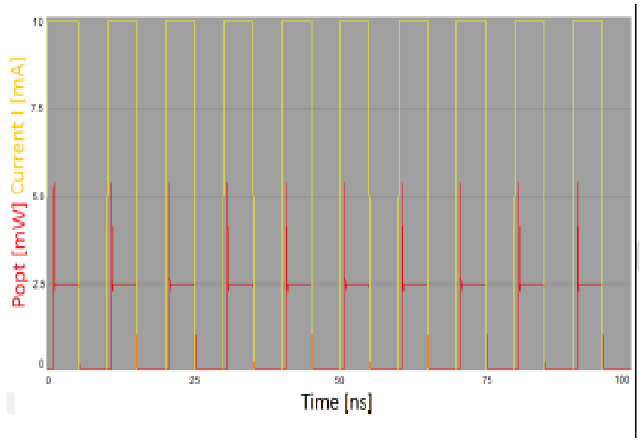

Fig. 8. *Popt for source current frequency 100MHz We notice the output optical power is more sensitive to noise*

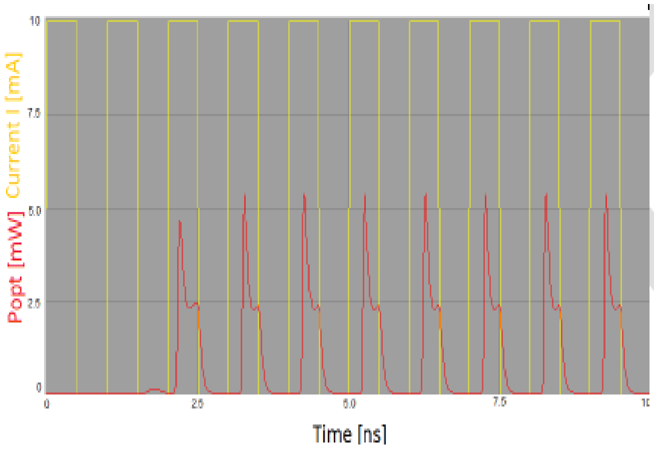

Fig. 9. *Popt for source current frequency 1GHz*
The VCSEL diode does not respond properly to the input current

The results below (Figure 10) show the optimal power (Popt) behavior as a function of the input current magnitude (I) depending on different frequencies

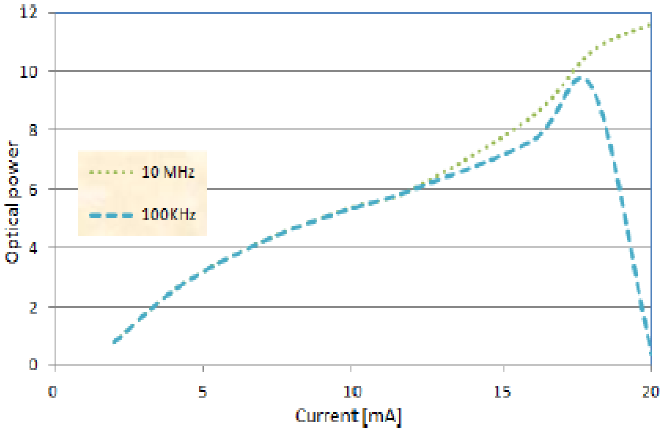

Fig. 10. *Popt vs current for different frequencies*
More the frequency increase, quickly the current reaches saturation

The increase of current intensity I affects the diode junction capacitance Cj and photons number, therefore it increase the optical power. The rise of the frequency has the effect of increasing the RIN noise which adds itself to the optical power

3.2. Photodiode

We assure that the active surface of the photodiode detects the entire laser beam emitted by the VCSEL laser diode. The photodiode is characterized by its large bandwidth in the case of transmitting broadband. The bandwidth may be defined by: [10]. The rise time and fall time of a photodiode is defined as the time for the signal to rise or fall from 10% to 90% or 90% to 10% of the final value respectively. The rise time represents the response time for laser pulse, according to the conventional standard 10% to 90% is shown in the following figure 11. This parameter can be also expressed as frequency response, which is the frequency at which the photodiode output decreases by 3dB.

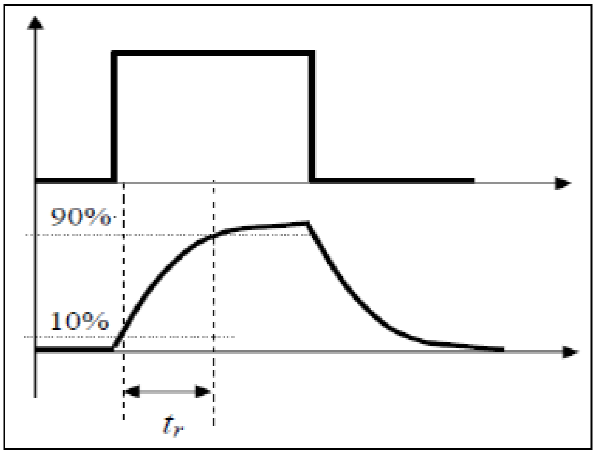

Fig.11. *Response time 10% 90%*

We proposed a photodiode model, which had the function to return current according to the optical power magnitude input Rshunt :“Dark” or “Shunt” resistance. The photodiode is reverse biased by E1. The main noise sources related to the photodiode are: shot noise, thermal noise, 1/f noise and dark current.

1. The shot noise: the noise associated with the carriers pass-ing through a potential barrier.
2. Thermal noise or Johnson noise is the result of random fluctuations of carriers within a resistance due to thermal agitation.
3. The 1/f noise: The previous noises above were white noise. There are other fundamental noises whose spectral densi-ty is constant in frequency. These are mainly low frequen-cy noises. It is proportional to the current.
4. The noise of dark current: The photodiode has current losses with or without illumination. This type of current undesirable and should be very low value is called dark current

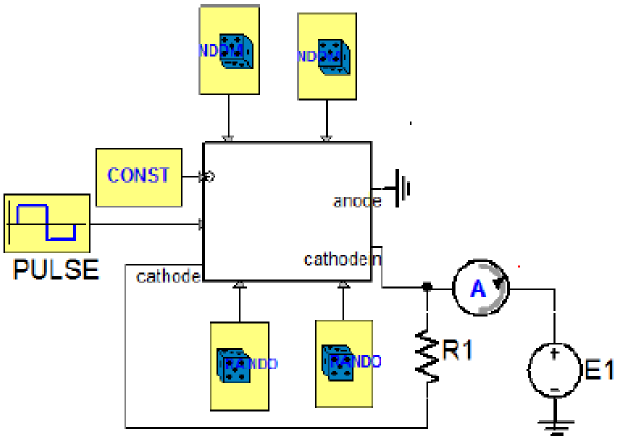

Fig. 12. *Photodiode Simplorer Schematic*

Random sources are returned outside the VHDL-AMS photodi-ode model to represent diode sources noises. The “CONST” input represents the optic wave length (850nm). Output current intensity is measured by an Amperemeter.

In our photodiode model, we assume that the rise time Tr=100e-12, so, The band width Bp = (0.35/tr) = 3.5 Ghz. In an optical link, the 1/f noise of the active components is converted near the carrier signal and contributes to degrading the spectral purity of the transmitted signal. The laser is usually the main noise contributor. A laser has a 1/f noise on both its frequency and its amplitude (RIN), and these two components are likely to be found around the converted transmitted frequency. The laser amplitude noise is naturally converted into electrical amplitude fluctuations by the photodiode. In addition, the photodiode through which a current, generate a low frequency noise in excess. Figures 13, 14 and 15, depected the 1/f noise effect on the photodiode current output amplidute fluctuations.

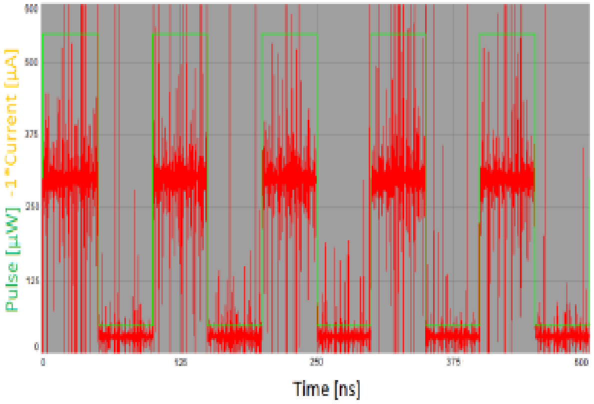

Fig. 13. *Photodiode current frequency 10 MHz*

The inherent noise of the photodiode is small, yet the compo-nent is capable of converting the amplitude fluctuations of the laser phase fluctuations due to a nonlinear capacitive effect. This conversion effect can be lessened by adjusting the optical power received and/or on the photodiode bias.

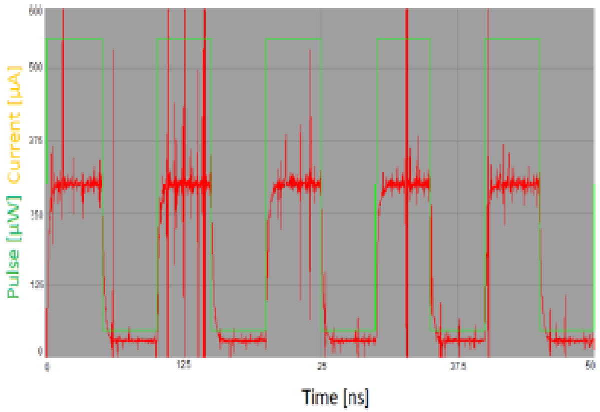

Fig. 14. *Photodiode current frequency 100 Mhz*
Less amplitude fluctuations, while the frequency increase.

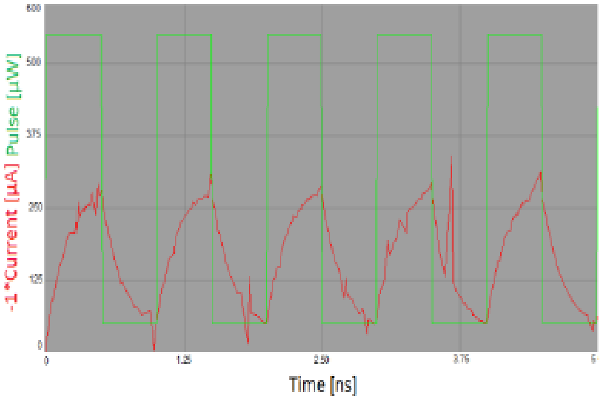

***Fig. 15**. Photodiode current frequency 1 **G**Hz*
The 1/f noise is virtually negligible impact.

When such a signal passes through an optical link, it is mod-ified in two ways: by the noise which is added to the signal and by multiplicative noise. Figures 13 to 15 indicate the noise effects on output signal depending on frequencies ranges. In the case of direct modulation, the bandwidth of the optical link communication is determined by the lower and upper frequency response limits of the laser diode or photodiode. The lower limit is set by the VCSEL and the photodiode bias, whereas the upper limit is determined by the cutoff frequency of the laser diode and the photodiode. The cutoff frequency laser diode is the most limiting parameter bandwidth. In our work we have an external modulation, so, the frequency response of the external modulator is also a limiting factor of the bandwidth of the optical communication.

4 CONCLUSION

Integrating an increasingly large number of IP cores on the same chip, make the future SoCs architecture’s communication design a challenging problem. With the aim to overcome this challenge, we have proposed OCDMA architecture. A part of the proposed solution (vcsel diode and photodiode) is simu-lated by VHDL_AMS. The simublated results highlight the frequency effect on the optical communication. Indeed, in high frequencies values laser diode didn’t work properly and an additional noise signal must be taken into account. In the next paper we will improve the accuracy of the simulated results by comparing it to the measured one

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