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PIN and APD Analysis for Optical CDMA based on The Proposed Radio over Fiber (RoF) Approach

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Abstract
In this paper, we will focus on the photodetectors that is used in OCDMA-RoF system. Photodetector Intrinsic Negative (PIN) and Avalanche Photodetector (APD) are commonly known photodetectors use to convert optical signal to electrical signal received from fiber optic cable. Bit error rate (BER) execution is evaluated for this OCDMA-RoF framework. OCDMA-RoF framework is seen as a promising technique for enhancing spectral efficiency, reducing the number of hardware use and meanwhile immune to electromagnetic inference (EMI) and radio frequency interference (RFI). The photodetectors have taken a gander at through software simulation. It has been found that the APD in this framework is prevalent than the PIN for all reproduction results. The exhibitions are portrayed through the effect of fiber length (km) with Bit Error Rate (BER) performance, eye-diagram analysis of both photodetectors and furthermore investigated the relationship of total power (W) losses in this system with the BER performance and finally the analysis of noise detection signal.

Keywords: APD and PIN; OCDMA-RoF; Bit Error Rate (BER); Electrical Power; Eye-Diagram; Noise Detection Signal

INTRODUCTION

Huge enthusiasm for multimedia data, higher data speeds, for excellent video quality and an extending number of users are putting load on wireless communication systems vendors to offer higher data rates. Lessen this pressure could be an expert by utilizing a microcellular framework, which suggests reducing the cell size, and thusly, it might diminish the power consumption of the mobile station [1].

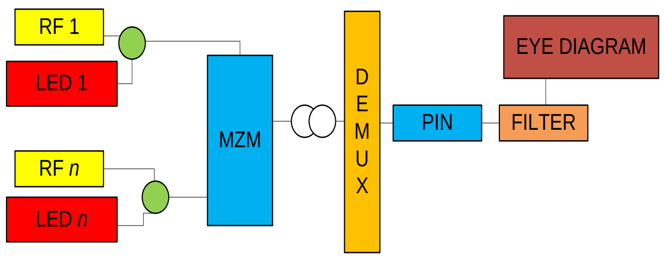

Figure I: Basic OCDMA-RoF Architecture

By using an optical fiber to partner central station (CS) with various remote, it can have streamlined the base stations (BS), it can essentially grow the network capacity limit, coverage and mobility what's more serve both fixed and mobile end users. The RoF offers a blend of high capacity optical fiber and flexibility wireless networks. This advancement is displayed to lessen the foundation cost and the complication of remote antenna units (RAU). Furthermore, RoF development is a contender to update the execution of wireless communication frameworks with the blend of vast bandwidth capacity (BW) and low attenuation attributes offered by optical fiber [2]. RoF presents the spreading of radio frequency (RF) signals over optical fiber links from a central office to RAU. Radio over fiber plan for both down and up-link paths are shown based on light on the digitized RF over fiber system. The digitized RF over fiber method is trust ready to improve spectral effectiveness and lessened equipment hardware, while the execution is restricted by inter-channel interference as a consequence of spectra associating of the regenerated IF signals which confines the signal to noise ratio [3]. There are numerous parameters which influence the execution of OCDMA-RoF framework on the channel in particular link distance, attenuation, geometric losses, transmitter loss, receiver loss, beam divergence, additional losses, etc. In the receiver side we can either utilize APD or PIN photodiode to receive the optical signal [4].

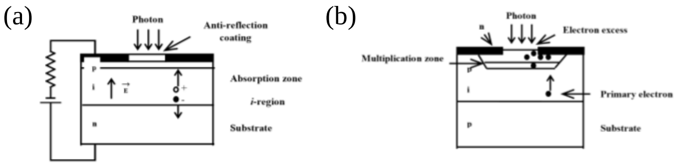

Figure II: Photodetector Architecture (a) PIN (b) APD [5].

Many interest in exploring the essential PIN and the more mind boggling, costly and eager for voltage APD photodetector exhibitions, for the most part because of the on-going and high-pressure commercial requests for cost cutting in the systems fusing these ultra-fast receiver [6]. APD photodetectors have been appearing as a better contender for long haul communications, because of their internal gain accessibility [7]. Notwithstanding, with the recent rapid developments in the innovation of both PIN and APDs, the bandwidth capacity of both is presently acknowledged at a higher bit rate, and this opens the way to new outline contemplations. In the PIN photodiode, thermal noise assumes the overwhelming part in the execution of the receiver. In the APD, both the thermal and shot noise is significant. Since optical correspondence frameworks are very perplexing and hard to interpret, it is helpful to anticipate the impacts of different parameters and attributes of the photodetectors utilized as a part of the optical system. This work mimics the impacts of fluctuating parameters on the exhibitions of both sorts of devices. As an apparatus, it can precisely anticipate the execution of any proposed framework to be actualized by breaking down the devices under development as keep in mind the end goal is to wipe out any execution degradation. The main goal of the fiber optic connection utilized is simply to transport information signals to and from the devices under investigation, dependably over long distances.

In this paper, we demonstrate a survey of two sorts of photodetector (APD and PIN), using a Mach–Zehnder sort interferometer wavelength converter into the OCDMA-RoF framework [8]. Bit Error Rate (BER) is executed to decide and demonstrate the best photodetector when apply into OCDMA-RoF framework. The Proposed OCDMA-RoF structure contains 8 OLTs and 8 ONUs.

PROPOSED OCDMA-ROF SIMULATION MODEL SYSTEM

Here, Figure III shows a schematic diagram of executing APD and PIN photodetector to test the execution of OCDMA-RoF framework. In this proposed outlined, two central stations will be used. Every central station involves 4 OLTs, in this manner the aggregate OLTs for two central stations are 8 OLTs. The pseudorandom bit sequence (PRBS) generator creates baseband signal which is utilized to tweak a high frequency RF carrier utilizing electrical modulation which will shift this spectrum of data signal at frequency carrier. It will produce a bit sequence of 0 and 1 with equivalent likelihood. From this simulation, the bit sequence length, typically is set to 128. The four pseudorandom bit generator is utilized to modulate four diverse electrical carriers having frequencies of 1.21GHz, 1.81GHz, 2.41GHz and 3.01GHz. These electrical carrier signals are joined together utilizing electrical adder.

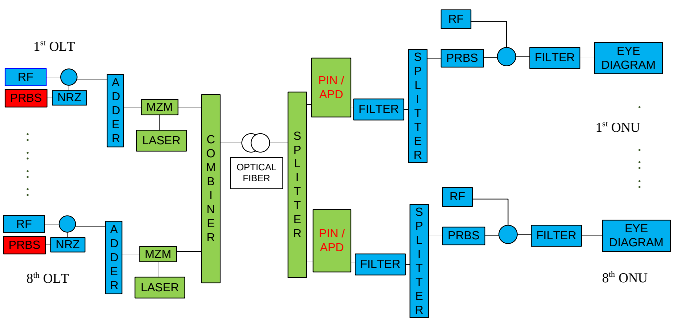

Figure III: Proposed OCDMA-RoF System Block Diagram.

A Mach-Zehnder modulator is driven by four distinctive electrical carrier source in every Central Station (Subsystem) to modulate with the continuous wave (CW) laser which change over the radio frequency to four diverse optical carriers. CW laser produces the light source of the 1550 nm wavelength and the power was set up at 0 dBm. All the four optical carrier for transmission are coupled together with other four optical carrier from Central Station 2 (Subsystem_1) utilizing the power combiner to end up one optical band signal. This optical band of the Mach-Zehnder signal is then regulated by OCDMA encoded signals. Later, the optical band signal is transmitted to the Base Stations through Single Mode Optical Fiber cable. SMF cable is the best option contrasted with Multi Mode Optical Fiber cable in light of the fact that an SMF directs stand out one mode furthermore competent to remove higher order modes. The attenuation is smaller since less light will experience absorption and scattering effects. Because of the OCDMA encoding of the signals which are required by various Base Stations, interception along the fiber link is roughly inconceivable and each Base Station could build a private and secure connection with the Central Station.

Consequently the security of OCDMA-RoF framework is amazingly enhanced and the Bit Error Rate (BER) execution for consecutive transmission can achieve 10^{-9} after the transmission over more than 45km SMF with no repeater or amplifier used. In any case, the fiber transmission is trusted ready to reach up to 60km for this enhanced outline. At the receiver area, the optical bands are part into two optical band signal for each Base Station by the power splitter since we have two Central Station (Subsystem and Subsystem_1) at the transmitter area. The first optical bands will be transmitted to the Base Station (Subsystem_2) and the second optical band is sent to Base Station 1 (Subsystem_3). PIN Photo-detector detect and demodulate the optical band and change over from optical to electrical signal (Baseband Signal). The output signal from PIN is then filtered by the Low Pass Bessel Filter to channel any higher frequency components before being sent to the Base Station (Subsystem_2). In each of the Base Station, one splitter is utilized to part the electrical signal and circulate to four ONUs. The procedure is rehash again utilizing APD photodetector to gather the information before making correlation in the middle of APD and PIN Photodetector. The complete simulation platform is shown in figure IV below.

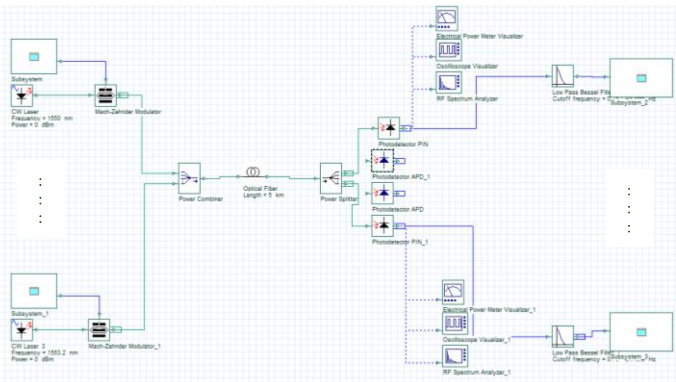

Figure IV: Schematic Diagram of Complete Proposed OCDMA-RoF System.

RESULTS AND DISCUSSION

The execution of OCDMA-RoF was exhibited by utilizing *OptiSystem* software from *Optiwave*^{TM} and the recreation parameters are appearing in Table 1. The simulation parameters, focused on the attenuation, dispersion effects and non-linear effects such as four wave mixing are initiating amid reenactment and indicated by running specific criteria to simulate the actual environment as close as possible. The exhibitions of the system were portrayed by alluding to the BER performance of APD versus PIN and power losses in this OCDMA-RoF system [9].

TABLE I. TYPICAL PARAMETERS FOR THE SIMULATION ANALYSIS [10]

Parameters	***Values***
Data rates	155Mbps
Operating wavelength	λ=1550 nm
Number of OLT and ONU	8
Attenuation	0.2 dB/km
Thermal noise	1.0 x 10-22 W/Hz
Dispersion	16.75 ps/nm-km
Fiber length (km)	5-100
Fiber loss	0.2 dB
Pulse width	0.8 nm

A. Bit Error Rate (BER) vs Fiber Length (km)

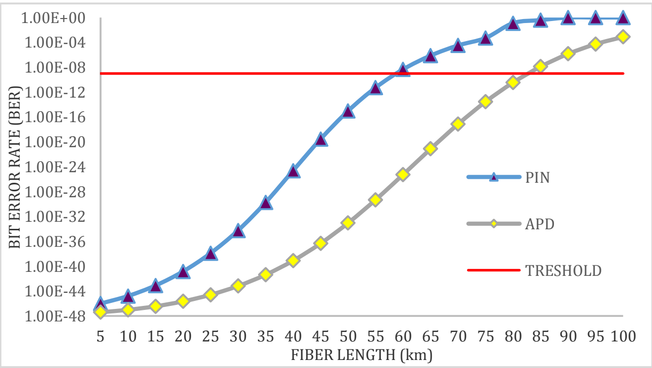

Figure V: BER Performance versus Noise Power of NRZ and RZ.

Figure V demonstrates the BER execution did against the fiber length for two sorts of photodetectors, PIN and APD at 155Mbps. The study is imperative to see the impact of PIN and APD on the performance of this purposed OCDMA-RoF system. The range from transmitter to receiver is tested from 5km to 100km with 1550nm wavelength. From the chart above, it can be seen that, when referred at the BER of 10^{-9}, the OCDMA-RoF perform better using APD photodetector compared to PIN photodetector. By utilizing APD, the fiber length achieved up to 80km long. In the interim, contrast with PIN, the fiber length only achieved 60km long. There are about 20 km margin of the fiber length in the middle of PIN and APD. Both APD and PIN are reverse-biased. The difference that made the APD performance very well in this system is that the absorption of a photon of incoming light may set off an electron-hole pair avalanche breakdown, creating up to 100 more electron-hole pairs. This feature gives the APD high sensitivity to detect optical signals, in contrast with the PIN photodetector. Be that as it may, as the fiber length diminish up to 90km, both NRZ and RZ are not able to keep up the BER exhibitions and drops beneath the BER floor rate.

B. Bit-Error Rate (BER) vs Power (W)

Figure VI exhibits the relationship of BER with the electrical power drop in this OCDMA-RoF system for APD and PIN. The hypothesis made as the power increment, the BER performance will increment also. From the diagram, as ought to be evident by using APD, the underlying perusing of power = $1.08\text{x}10^{-7}$ Watt and the BER at $3.99\text{x}10^{-48}$. Appeared differently in relation to the PIN, the underlying perusing of power = $1.20\text{x}10^{-8}$ Watt and the BER is $9.72\text{x}10^{-47}$. This proves the OCDMA-RoF system perform well as the power increase, the BER execution of APD and PIN for this OCDMA-RoF system increment. It is in like manner exhibited that APD is considerably more suitable to be associated with this system subsequent to the basic scrutinizing of BER performance for APD is better than PIN. When looking at the estimation of the power for both photodetectors, APD photodetector has unquestionably been more sensitive to detect optical signals and in the meantime ready to prevent any power losses happen in the receiving zone. The dominant noise in the PIN photodiode is that of thermal noise effect from the different circuits contained in the photodetector, for example, the resistance and the amplifier which create thermal agitation of electrons which therefore impacts on the photodetector responsivity, however the APD photodiode opposes against the thermal noise because of its internal gain created by the avalanche process, yet this procedure causes an ascending of quantum noise that lessens the photodiode detection speed, this is due to the noise of multiplication generated particularly in APD photodiode by impact of carriers in the depletion region.

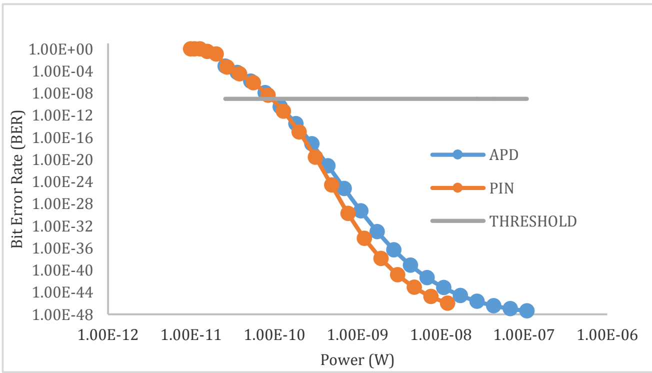

Figure VI: Power Losses of OCDMA-RoF System for PIN and APD.

C. Eye-Diagram Analysis

Figure VII shows the effect of the signal degradation as the fiber length is expanded up to 80km for both photodetectors. Utilizing APD as a part of this proposed plan, the framework has a large eye-opening between the top and base level. The stature of the eye-diagram at the predefined time interval demonstrates the noise margin or noise immunity of the framework.

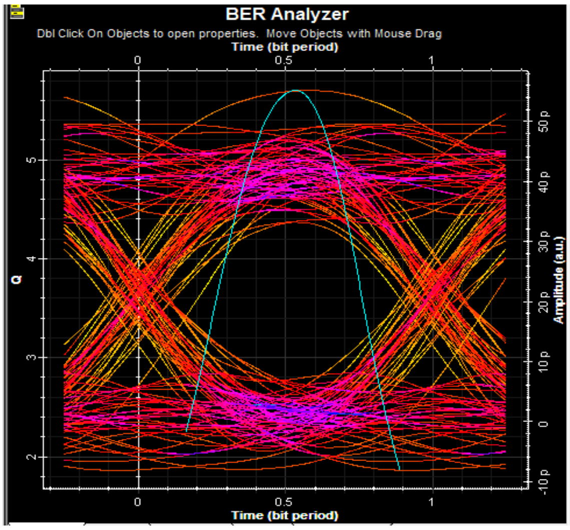

Figure VII: Eye Diagram of APD at 80KM Fiber Length.

Contrasted with PIN photodetector (FIGURE VIII), the eye-diagram is closer and smaller and in this way make the framework hard to separate somewhere around ones and zeros in the signal. The execution of PIN is impacted by both thermal and shot noise in the PIN photodetector. The previous influences the execution of the PIN intensely, while the shot noise influences it just delicately. Referred to the APD case, the execution is influenced incredibly by the shot noise. Basically, the PIN yields a higher sign to noise (SNR) than the APD, because of the APD shot noise. Notwithstanding, similarly as the shot noise is concerned, the APD generates a higher SNR than the PIN at equivalent optical power source. This change in the SNR is because of the APD gain, which duplicates the photocurrent by a multiplication with variable "M" therefore enhanced the affectability when detecting the optical signal.

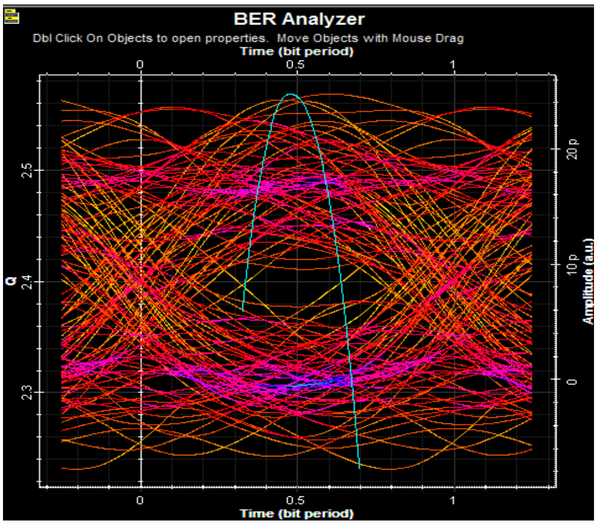

Figure VIII: Eye Diagram of PIN at 80KM Fiber Length.

D. Noise Detection Signal Analysis

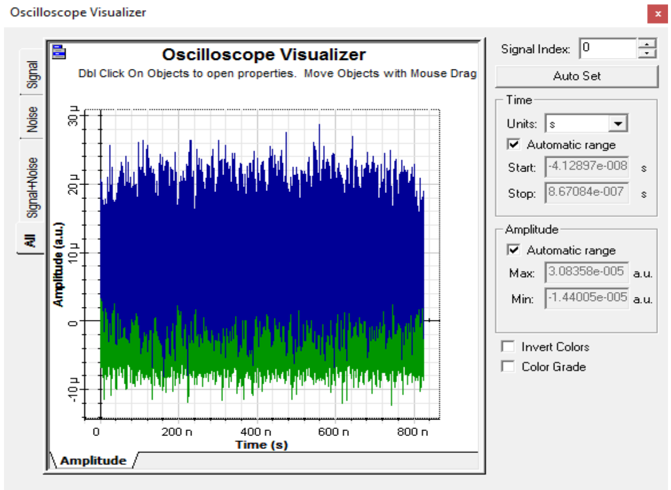

Figure IX: Noise Analysis of APD at 80KM Fiber Length.

The figure IX and figure X presents both the identified signal and the noise of photodetection detected by an oscilloscope visualizer. The green signal illustrates the noise signal in this proposed OCDMA-RoF framework. It is observed that, APD detect more noise signal compare with PIN. As the internal APD gain increases, more detected signal and the photodetection noise increase, this involves a degradation of signal-to-noise ratio caused by the quantum noise which is amplified more rapidly than the detected signal. This phenomenon is due to the noise of multiplication also known as avalanche noise because it is only generated in APD photodiode [11].

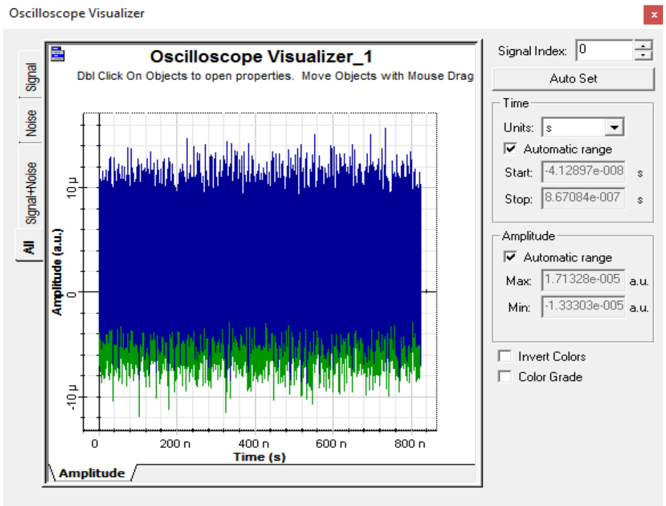

Figure X: Noise Analysis of PIN at 80KM Fiber Length.

CONCLUSION

In outline, we have thought about and investigated the exhibitions of PIN and APD photodetector for use in an optical system. The gain of the APD photodetector, which brings about higher SNR value, has made it more suitable for long haul communication, as a high performance receiver in high data transmission applications and bit rates, where the expense is unavoidable. For this OCDMA-RoF framework, the execution is best when utilizing APD as photodetector. This framework accomplished fiber length up to 80 km long contrast with PIN photodetector, it just accomplished fiber length of 60 km. Also, it is a decent hopeful in high-delicate system access applications. We found that noise increments with the data transfer capacity of both photodetectors, thus it is essential to improve APD sensitivity performance. This particular sensitivity performance is required to be equivalent to the auxiliary electronic pre-amplifier input noise. This is the colossal favorable position of the APD over the PIN, where its gain does not take an interest in the noise. For sure, it minimizes and counteract other noise produce in the framework.

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REFERENCES

[1] Y. Liu, G. Zhang, Q. Li, WDM/TDM hybrid GPON technology, in: 2011 Symposium on Photonics and Optoelectronics (SOPO), vol. 2, May 16–18, 2011, pp. 1–3.

[2] Y. Hsueh, Z. Jia, H. Chien, A. Chowdhury, J. Yu, and G.-K. Chang, (2011), J. Lightw. Technol. pp. 1105-1111.

[3] Y. Yang, C. Lim, A. Nirmalathas, Experimental demonstration of multi-service hybrid fiber-radio system using digitized RF-over-fiber technique, J. Lightwave Technol. 29 (July (14)) (2011) 2131– 2137.

[4] Singh, M. (2015). Performance Comparison between PIN and APD Photodiodes for use in Free Space Optical Communication Link, *2*(8), 25–28.

[5] Boudkhil, A. (2015). Analysis of Fundamental Photodetection Noises and Evaluation of PIN and APD Photodiodes Performances using an Optical High Debit Transmission Chain Simulated by Optisystem, 115(18), 21–29.

[6] G. Wang, T. Tokumitsu, I. Hanawa, K. Sato, M. Kobayashi, Analysis of high speed p–i–n photodiode S-parameters by a novel small-signal equivalent circuit model, IEEE Microw Wireless Compon. Lett. 12 (10) (Oct 2002) 378–380.

[7] K.F. Li, D.S. Ong, J.P.R. David, P.N. Robson, R.C. Tozer, G.J. Rees, R. Grey, Avalanche photodiode (APD) noise dependence on avalanche region width, in: 5th Device Research Conference Digest, 23–25 June 1997, pp. 170–171.

[8] NORTE D., WILLNER A.E., Experimental demonstrations of all-optical conversions between the RZ and NRZ data formats incorporating noninverting wavelength shifting leading to format transparency, IEEE Photonics Technology Letters 8(5), 1996 , pp. 712–714.

[9] Rashidi, C. B. M., Aljunid, S. A., Ghani, F., Fadhil, H. A., Anuar, M. S., & Arief, A. R. (2014). Cardinality enrichment of flexible cross correlation (FCC) code for SAC-OCDMA system by alleviation interference scheme (AIS). Optik - International Journal for Light and Electron Optics, 125(17).

[10] Rashidi, C. B. M., Aljunid, S. A., Ghani, F., Fadhil, H. A., & Anuar, M. S. (2013). New Design of Flexible Cross Correlation (FCC) Code for SAC-OCDMA System. Procedia Engineering, 53(0), 420–427.

[11] R. Alabedra, B. Orsal, A. H. Maatougui, K. D. Raniriharinosy, P. Gori and C. Boisrobert, "Report of ionization coefficients and noise in avalanche photodetectors Hg0,44 Cd0,56 Te with λ = 1600 nm",Annals of Telecommunications, Vol 43, Issue 3-4, March/April 1988, 117-122.

[12] Decoster, D. and Harari, J. 2002. Optoelectronic detectors. Hermes-Science. Paris. 17-20, 26-28, 205-214.