APPLICATIONS OF THE LASER LIGHT WITH SPATIAL INCOHERENCE AND BIONIC OPTIMIZATION TO THE OPTICAL WIRELESS COMMUNICATIONS

Samuel Ángel Jaramillo Flórez
Universidad del Quindío, Facultad de Ingeniería, Programa de Ingeniería Electrónica
Avenida Bolívar Calle 12 Norte, Armenia, Quindío, Colombia
samuelangel@uniquindio.edu.co

***Abstract*— It is presented an optical communication transmission/reception system with an optic channel of free space where is modulated the transmitter laser through a set of spherical lens and optical fibers that expand the beam of light indoor, producing multiple punctual images that permit to optimize the bandwidth of the system.**

***Index Terms*—Bioelectronics, broadband, Free Space Optics (FSO), optoelectronics, spatial modulation.**

I. INTRODUCTION

The competitive companies of telecommunications, which offer new services, must fight to install alternatives of broadband access networks to the subscriber's telephonic networks already installed in the majority of homes and offices. The costs of installation and operation associated with the implementation of the transmission and commutation links in the optical access networks might justify when the subscriber's density was promising sufficient money to recover the investments and thus, to obtain the awaited earnings. In the case of the economical and political estimations of the optical network's company, it does not allow the arrival of the fiber up to the facilities of the final user. It is necessary the installation of access networks named "secondary" that achieve a relation QoS vs. High Financial costs in order to the competitive company achieves the programmed profitably and offers the awaited service. This, for the service of accesses of broadband (to Internet, for example) for residential users and companies with not very high information flows [1]. On the other hand, there are local area networks (LANs) that need links of low budget and facility in his installation. Also there are needs that are not completely satisfied in a proper way such as access networks for users with low mobility (or mobility of low speed), which need low costs of connection and multiple applications. A wireless technology, of low consumption, cost, high accounting, capacity adapted to the needs of such users' classes and high facility of installation, would turn into a solution of advanced into environments where the density and the growth of final users are very irregular, much more since the point of view of the number of subscribers like for the geographical areas and the random locations in which these are. A set of network equipments and devices based on the transmission for infrared light, is being offered by several manufacturers, including peripheral of computer, hand devices and all kinds of devices that obtain a good applicable capacity that accede to high speeds on Internet, constituting a network access of optical complementary technologies: fiber and free space optics transmission (FSO) [1].

Bioelectronics takes of biology the optimized elements for doing a copy and building technological mechanisms with functions based on living bodies' components. Telecommunications and biology present an analogy between the optical receivers and the insect's eyes, whose forms are adequate to receive signals from a transmitter, and which have been improved by the nature during millions of years in the environment adaptation. The sizes and the forms depend on the direction of the waves and on the radiation pattern of these biotransmitters and bioreceivers (ommatidium of insects eyes), which are similar to the optical communications emitters and photodetectors. The growth of telecommunication services makes necessary the optimization of the bandwidth of the transmission channels. Although the optic transmission is considered as the ideal as regards the attenuation and distortion characteristics that make that it possesses a better relation bandwidth-longitude, the demand of more transmission capacity forces to take advantage of them efficiently. High costs, generated when deploying Optic Fiber Networks at the transport level, together with other factors that avoid PONs arriving to home and/or office, have propelled the design and implementation of partially optical networks (FITL), including an alternative that uses infrared light.

In this paper it is presented an optical communication system with optic channel of free space, where is modulated the transmitter laser through a set of spherical lens and optical fibers that expands the beam of light indoor, producing multiple punctual images that permit to optimize the system's bandwidth.

II. INFRARED TRANSMISSION SYSTEMS

Information transmission systems based on sending and receiving optical signals, wired or wireless, work over infrared (IR) electromagnetic spectrum range. Transmission systems based on optic fibers, propagate infrared light along low attenuation and high linearity areas such as transmission media, which are in the wavelength regions of 850 nm, 1310 nm and 1550 nm. Different to that optical systems by fiber, optical transmission systems through the free space do not use a guided medium to propagate the signal. In such systems the designers do not take care about the way of using infrared energy in the wavelengths aforementioned. But their design aims over the physical level, concentrates on getting the more propagated distance without fading infrared light power below that observable by the detection system. An infrared transmission system is composed by a transmission device, a reception device and a propagation medium with characteristics for optimal optic transmission.

The transition media is the vacuum (in this case the air) and presents a sum of factors about the electromagnetic propagation resistance on infrared wavelengths. Such a sum is the result of free space losses (that can be calculated by using the Friis expression), lobe fading, intensity losses caused by high temperatures (by the generation of vapors that makes refractions), atmospheric depressions (rain and fog) and, as a primordial factor, the need of a line of sight between transmitter and receiver to establish the link. The emitter system for infrared transmission (see Figure 1) is composed by a modulation block and a radiation source on that spectrum region. Such a radiation source is generally constituted by an infrared emission diode (IRD) or infrared laser diode (ILD) manufactured on Gallium Arsenium, and whose crystal case can reach highly collimated radiations, or well lobe widths of up to 30° (see Figure 2), depending on if it uses, or not, physical optic for its output structure (mirrors and convergent lens). Detection systems, or receivers, are composed by photodiodes or phototransistors, made of Silica or Germanium, being Germanium the best absorber of intensity over a wide infrared spectrum range (see Figure 3).

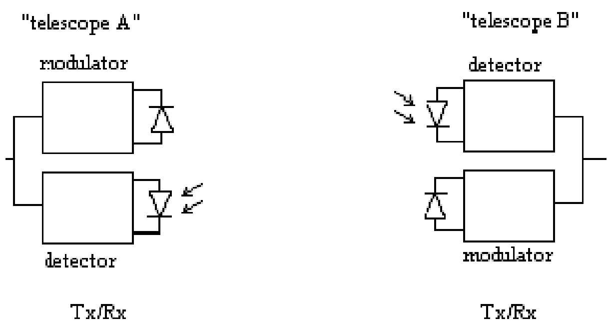


Fig. 1. Simplified sketch of a bi-directional infrared transmission system.

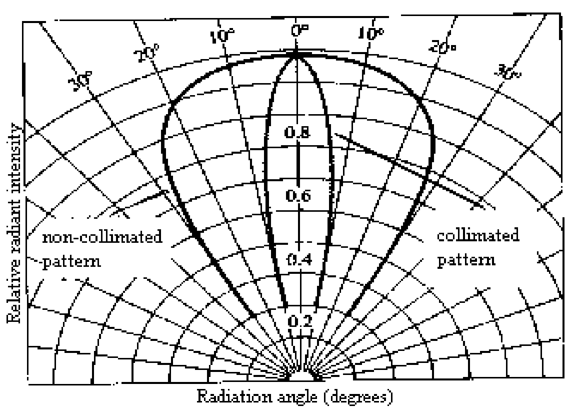


Fig. 2. Typical radiation patterns, collimated and not collimated, for an infrared source diode.

III. NETWORK PROTOCOLS FOR INFRARED ACCESS

Having high velocity, access networks are an idea that implies thinking about two non-hierarchical levels SDH/SONET networks providing the multi-technology access networks with high payload bandwidths throughout all its add/drop multiplexers (ADM access nodes).

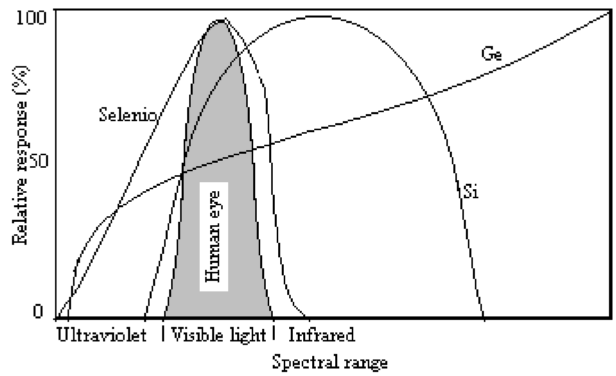


Fig. 3. Spectral sensibility of Ge, Si and Selenium regarding human vision.

The protocol paradigm of medium access over passive broadcast networks, or even in active multiplexed networks, is the Asynchronous Transfer Mode (ATM). It can calculate distances in terms of clock pulses, in order to obtain a transmission convergence and make the broadcasting to send and to receive of ATM cells. These cells are inserted on the SDH/SONET cells payload. So, with the establishment of ATM virtual circuits, and at the same time using synchronous digital hierarchy virtual containers, the subscriber's access into the transport network, can be done by interconnecting them with data networks: Internet, or other private and public networks.

Passive Optical Networks (PON) have the architecture that uses ATM as its data link and medium access control protocol. Although actually exist two well known and proven protocols: Ethernet and Gigabit Ethernet, are intended for bringing efficient protocols and interfaces, set to communicate subscribers and ISPs.

All Information Appliances that are being developed in the new wave of Home Networking, uses Internet access through gateways connected to access networks. These environments will be very important business targets, taking into account the infrared transmission as an efficient alternative, costs-effective and easily deployable along Internet broadband access networks. There are two main wireless technologies to use in home networking products: Infrared (IR) and Radio frequency (RF). Until now, most of the developers and vendors has seen infrared networks like a corporate medium-low scale LANs technology or as a technology that makes possible interconnecting several appliances (information applications or devices) into a house, room, SOHO (Small Office/Home Office) or whatever business with medium data flow level. However, the scope is that in the near future, besides having LAN infrared networks inside a house, it also can obtain broadband access through networks based on IR topologies like those proposed on the next section. In addition to the use Ethernet and ATM, and even directly SDH/SONET frames, as the interfaces and protocols for data link and medium access control, in the world there is *de* facto protocols proposed by Infrared Data Association (IrDA), among other proprietary ones, see Figure 4, and adopted by all information appliances and access networks developers, designers and manufacturers that use this technology, including application software made by Microsoft and Linux [1].

IrTRAN	IrObex	IrLAN	IrCOM	IrMC	Aplication
LM-IAS	Transport Protocol Tiny-TinTP				Transport
Link Management Ir-IrLMP					MAC
Link Access Protocol -IrLAP					LLC
Serial Asychronous (9.6-115.2 Kbps)	Serial Synchronous (1.152 Mbps)	Sync 4PPM (4 Mbps)			Physical

Fig. 4. IrDA Protocols Set.

When an access network is implemented using equipment based on the protocols set of IrDA (see Figure 4), ATM and SDH/SONET protocols, and hence TCP/IP protocols (the most used over ATM), would perform its functions over the Network Layer (having into account the TCP/IP network model). On the other hand, using only the standardized IrDA Physical Interfaces and Protocols, ATM or Ethernet standards adopts the roles of data link, transmission convergence (in the ATM case) and network layer (TCP/IP, ATM and/or Ethernet) (see Figure 5).

IV. FSO ACCESS NETWORKS TOPOLOGIES

Fiber Into The Loop (FITL) constitutes the paradigmatic revolution at the moment. The longer penetration the optical fiber has in the local loop side, the longer data and services capacities could be offered by the optical carrier (network operator) and the other competitive carrier companies (CLECs). Access networks containing some part (or parts) of it and run over optic fiber links are classified in Fiber To The Home (FTTH), Fiber To The Building (FTTB), Fiber To The Curb (FTTC) or Fiber To The Cabinet or pedestal (FTTCa) (see Figure 6) [2]. On the classification above, the most indicated environments where combining optic fiber with short range, high performance transmission technologies are: FTTC and FTTCa. Infrared light links are more reliable and faster when the range (distance) that it must cover is smaller. Therefore, designing access networks for distributing bandwidth among certain areas (which everyone covers some hundreds of meters in diameter) is a new opportunity that can be used by competitive and news companies to deploy access networks driving the optical fiber deployed up to the Curb or Cabinet, that can be offered by high velocity transport networks carriers (see Figure 7).

TCP	UDP		Transport
TCP/IP			Network
ATM Transmision Convergence			MAC
ATM			LLC
Serial Asynchronous (9.6-115.2 Kbps)	Serial Synchronous (1.152 Mbps)	Sync 4PPM (4 Mbps)	Physical

Fig. 5. Application of IrDA protocols in an access network environment, for example in order to get Internet access.

A Passive Optical Network (PON) topology has an OLT (Optical Line Termination), an ODN (Optical Distribution Network) and, in order to make the interface with multitude of complementary access technologies, considered as "secondary" access networks (of course, including FSO), an ONU (Optical Network Unit). These are the PON components and elements, which represent the most designed and deployed access network configuration throughout the globe (see Figure 8) [2].

Choosing network element capacities is the key for introducing FSO, including ILEC's or CLEC's ONUs and carrier's ADMs that communicate with infrared user terminals on the one hand, and with those ONUs on the other hand. It must be considered the protocol set used for Mux/Demux infrared access equipment, since PONs has standardized processing velocities working over ATM and, has actually developed, over the Ethernet and Gigabit Ethernet protocols. ONU has four main parts: Interface with ODN part, ATM cells assembling and multiplexing part, adaptation functions part and, with standardized Q3 interfaces, OAM control and management part.

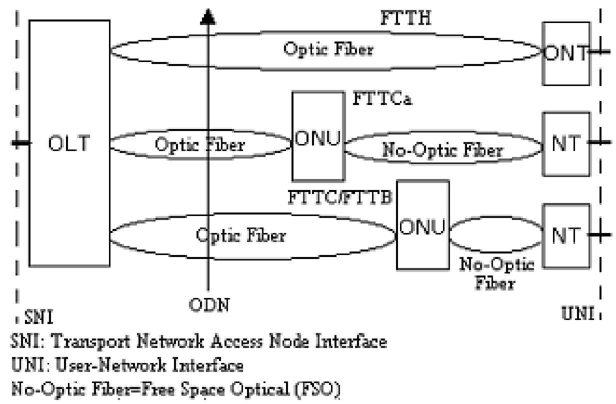


Fig. 6. FITL Topologies enabling FSO.

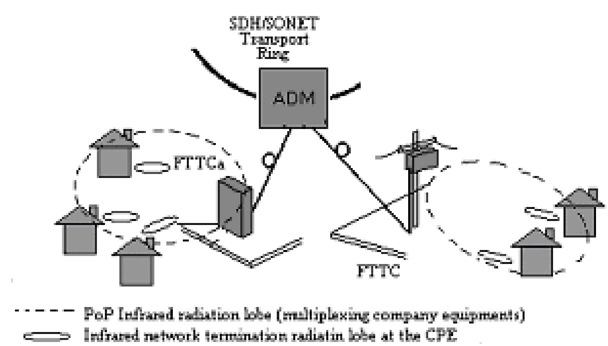


Fig. 7. FTTC and FFTCa topology environments using Free Space Optics (FSO).

The links for infrared light are more reliable and fast, since the distance that they should cover be minor, for which to design infrared access networks distributed in areas of a few hundreds of meters of diameter is an opportunity that carries competitive companies and new companies can use to install access networks taking advantage of the laying of optical fiber on Fiber To The Cabinet or pedestal (FTTCa), which there can offer the carries of networks of transport of high velocity [1].

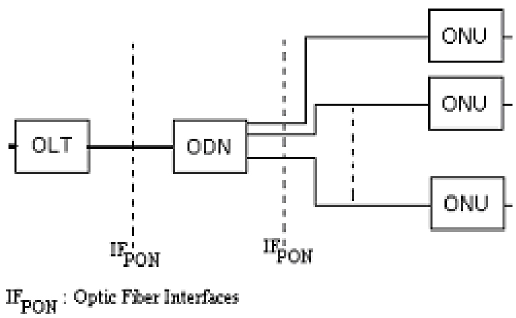


Fig. 8. PON Components.

FSO: Free Space Optics consists on the use of the propagation of infrared light across the free space (the air) to transmit information (see Figure 9). The objectives, as regards the systems of transmission FSO, consist on developing links point - to - point that work on the most reliable form that could be achieved and on the capacities in velocity of transmission and distance needed, in order to use in systems of networks of computers LAN, lines rented of high velocity for corporations and medium companies, systems of safety transmission to protect the transmission of sections of networks of optical fiber or other transmission systems and, finally, access networks to provide proper velocities of networks of optical fiber for residential users and of SOHOs.

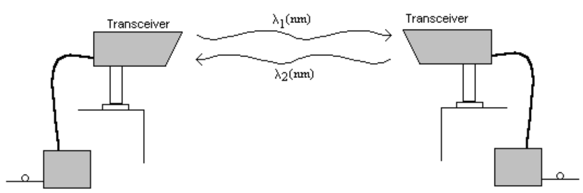


Fig. 9. System of simple transmission FSO.

The applications above mentioned are classified inside the problem of the “last mile of broadband “on the part of the manufacturers companies of systems FSO and of access networks of Broadband Access Networks. The Figure 10 shows the typical topology based on which they have designed and installed: networks of access and, in general, networks of last mile. Using FSO in FSOAN (FSO Access Network) of broadband it has given till now in systems point to point. Due to the fact that was already mentioned it brings over of the classes of links FSO that are accepted to be included inside the classification of "last mile", the topology of the FSO network only changes into some few elements. In the Figure 11 appear the classified cases. FSO are two: nodes elements of commutation and nodes elements of the system of transmission. The network elements that form the set of an access network A topology point to multipoint can be designed and installed by a number *n* of nodes and a number *n-1* of links FSO. The nodes fulfill the functions of commutation, routing and multiplexing needed according to the protocols and the technologies of access network and transport network used. In the Figure 12 a network shows itself point to multipoint. In this one two classes of nodes can be defined: The node of access to a network of transport and the nodes of access to the FSOAN.

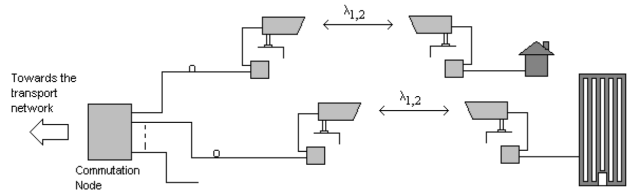


Fig. 10. Basic topology of access network FSO.

There are two kinds of transmission and reception system FSO. The first one, and more used, is the one that realizes a double conversion: optics - electric-optics O-E-O (see Figure 13). The second one does not do really a conversion in the energy: optics - optics, though the latter might be thought as optics (fiber) - optics (free space) O-O.

In the Figure 14 appears a system FSO of the class that has qualified like O-O. The signal that is inserted in the transmitter propagates for an optical fiber, generally with a wavelength of 1550 nm. The above mentioned signal is amplified in a subsystem amplifier doped by Erbium (EDFA: Erbium Doped Fiber Amplifier) and it is then emitted to the free space across a system of lenses that carry out a function of concentration of the wave that comes of the optical amplifier and leave the wave goes out to the free space. In the receiver system the infrared wave passes for a system of convergent lenses, which insert it in an optical fiber.

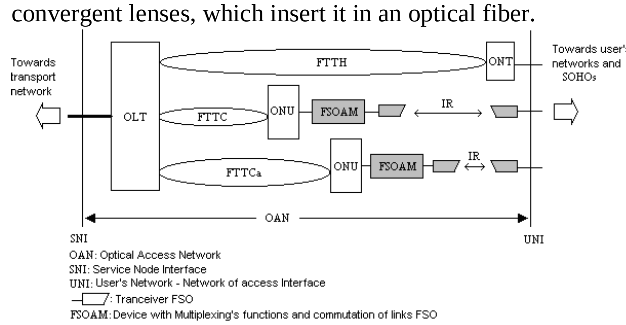


Fig. 11. Cases classified as the concept of access network.

V. FSO NETWORK ARCHITECTURES

At this point, the most important part to have into account is the interface between ONUs and the concentration and multiplexing equipment in the secondary FSO. The key is to understand an ONU function (see Figure 15).

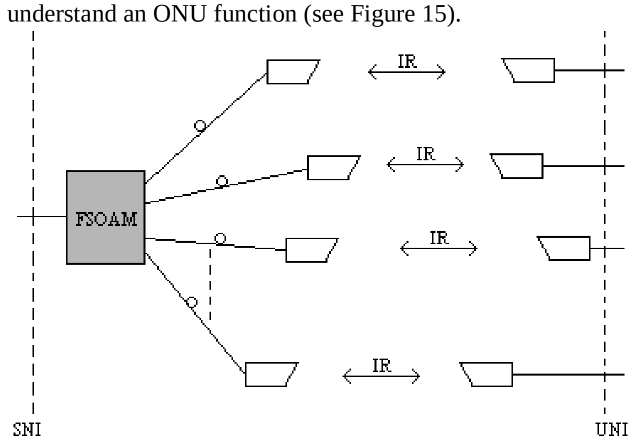


Fig. 12. Pseudo-topology point to multipoint.

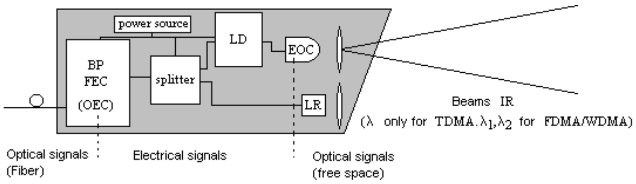


Fig. 13. FSO with conversion O-E-O.

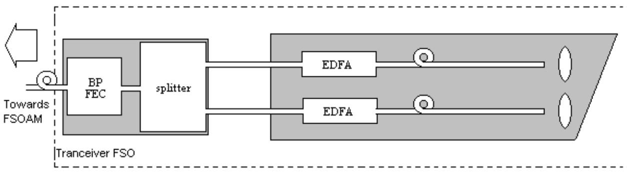


Fig. 14. FSO without conversion of energy (O-O).

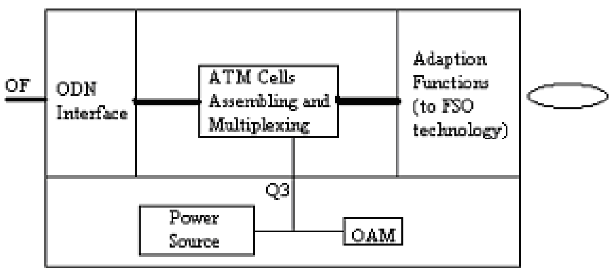


Fig. 15. Internal simplified scheme of an ONU.

For the FSON/PON, data interface and physical part are necessary for ONU's respective adaptation functions designing send-receive and infrared access Mux/Demux for broadcasting multiple users and, in some special cases, for adapting data flows driven through point-to-point infrared links. The integration of ONUs, Mux/Demux and ATM (or Ethernet) assembling cells systems, is done in one functional package or modular equipment in the same way that it was done with DSLAMs (Digital Subscriber Lines Multiplexer) and ATM switches. In the infrared scheme, such integrated equipments include all logical elements necessary to operate and do an interface with ATM/Ethernet PON systems, realizing to multiplicity of subscribers to IR links and doing the assemble and management of unit cells on the protocol used for data link and access network in general. An integrated system as that one described above, would exhibit an access network topology for both FTTC and FTTCa, having into account that in-pole installations as a particular case of FTTC is the most indicated choice for making a secure line of sight infrared broadband links.

VI. ACCESS NETWORKS MODEL DESIGN APPLIED TO FREE SPACE OPTICS

It is necessary to make a definition regarding the levels at which telecommunications networks can be studied, just for determining on which of those levels it is possible to do the reasoning; all of this with modern broadband access networks on the scope and especially in the case of Free Space Optics. Here, it is offered a choice that consists on four abstraction levels of organization. The four levels, that compose the telecommunications network model design, have been proposed regarding to precedent models and looking for the most complete model, that save the designed work from imprecision, interpretations and less complete descriptions used in the literature. Management, Functional, Architectural and Physical levels, are just the first step to reach such problem solution. Besides, it is also good as point of reference in the multidimensional space of telecommunication networks design. It will only be taken into account the functional level from the four levels mentioned above, hence in the example exhibited on the next section it will be exposed several aspects that prevent the need for designing at the management level and, much less, at the architectural and physical level, where manufacturers do their work.

A. Functional Level

At this level engineers and scientists are thinking about the information concerning the transmission capacities the network must match. Thinking about that as an organization of sub-systems, and taking those, at the same time, as functions correlating input and output capacities. At this point it is important to think about geographical extensions to be covered by the network, transmission magnitudes for the services required by subscribers, dividing the network into levels and sections (actually in two levels: Transport level and Access level) and its organization using blocks or parts (subsystems) that perform the access, switching and transporting global functions. The Telecommunications Management Network (TMN) must be taken into account designing at this abstraction level, since it requires its own capacity, functional blocks and interfaces to intercommunicate with manageable network elements [3].

B. Functional Design Level Applied to Secondary FSO Networks.

In the section above were defined the activities that will be done on the next example. A secondary FSO network that offers broadband access to Internet requires basically of a PoP (Point of Presence), infrared subscribers links multiplier equipment and Infrared Network Terminations (INT) (Figure 16), which are directly connected to the consumer premises equipment. Using an infrared-through-the-window (IrTW) scheme, the link between PoP (composed by an ONU and an infrared multiplexer) and consumer premises equipment consists on an infrared electromagnetic energy beam flying across the home or the office windows glasses. About the TMN, it will only be taken into account that PoP equipment, that includes carrier's ONUs and infrared subscriber's access multiplexing equipment owned by the CLEC (EtherLEC, ATMLEC or whatever broadband access company), it must have into its functions a block system, whose interface is Q3, necessary for control and management (OAM) of the capacity resources agreed with the consumer by means of SLA (Service Level Agreement).

In the analysis of geographical extension to be covered it is necessary to consider that reachable distances for infrared links show much variation with the different manufacturers. However, there is a "virtual agreement" about those access links: For the scenario of "secondary" FSO access networks, those must be among several hundred meters and maximum 500 meters.

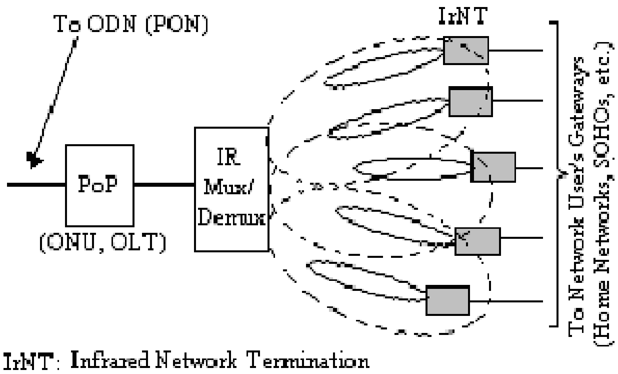


Fig. 16. Simplified scheme of a "secondary" topology based on FSO.

Finally, and before we are going to play with some numbers, it must be taken into account that capacities of PoP equipment owned by PON proprietary carrier companies (ILECs, EtherLECs or CLECs), can be used to estimate the users quantity that it can serve and the quality of service (QoS) provided (maximum transmission velocity for each user).

VII. BIONIC

The movement of the animals in the air and in the water decides the evolutionary development of the biological systems, adapted to the solution of the problems of the aero and hydrodynamics and in a series of cases that are not for the present accessible to the artificial devices. The dolphin's skin possesses special properties that allow diminishing any resistance to the movement of the animal. The flight of the wings jambs or that land of the birds is used as example to construct the flying devices for the man. The branch of the science dedicated to the technical employment of the mechanisms developed by the living nature is named Bionic. It was initiated by Leonardo da Vinci, who projected the wings for the flight of the man. He was the founder of the Biomechanics in its set on having studied for the first time the march, the career and the jump of the man. To the Biomechanics also makes reference to the receipt of the mechanical oscillations and the orientation of the body for the organs of balance (organs otolites of the ear). The biomechanics researches are very essential for the technology and the medicine. The Biomechanics and the Bionic are branches of the Biophysics.

VIII. INSECTS' EYES

The eyes exist in several plagues in which both the non-insects and the insects are included. Spiders like the black widow are plagues, but they are not insects. Insects possess three principal parts in their body, which are: (1) head, (2) thorax, (3) abdomen [4]. Spiders have two principal parts in their body: (1) abdomen, (2) cephalothoraxes. In the top part of the cephalothoraxes of a black widow spider arranged in two rows, one on the other one, possesses eight simple eyes. (Some spiders have only six simple eyes). Some insects have both types of eyes, simple and compound, as the bees of honey, the yellow jackets and the flies. These simple eyes are usually placed in a triangular model in the front or in the top part of their head. In these examples, the simple eyes play the function of meter of light and beyond this, there are the speculation that they serve them somehow to orientate the insect while this one is flying. The majorities of the insects possesses only compound eyes and are totally different from the simple eyes. These compound eyes can be very small in relation to the size of the head of the insects, as in the case of fleas. They can cover much of their sides, face, or in the above part of the head, as in the case of flies and cockroaches. A meticulous sight in the surface of a compound eye reveals that is divided inside a number of hexagonal facets, all facets in the measure as a surface of mosaic in tile (see Figures 17, 18 and 19). Every hexagonal unit has its proper lens and its proper retina and shows an independent image from any another unit in the mosaic. All the hundred of facets across the face of the compound eyes produce proper pictures. Besides this, an insect can observe an object from different perspectives, all at the same time. These types of eyes do not produce a clear vision as can focus the lenses to be able to do it in the eyes of the human being. There are "pre-molten and pre-measured" lenses. Nevertheless, they are a great help in the determination of the movement (probably hundred or more units choose this movement simultaneously) and they help to detect a change in the intensity of the light. To reduce the field of vision of every ommatidium is sufficient to diminish the diameter d of his optical small stick, making it commensurable with the dimensions of the image of diffraction, according to one show in the Figures 20 and 21. The decrease of the diameter of the optical small stick up to a minor dimension that the diameter of the image of diffraction does not reduce the visual width of the ommatidium but it reduces the photosensibility, since the number of photoreceivers in the small stick will diminish.

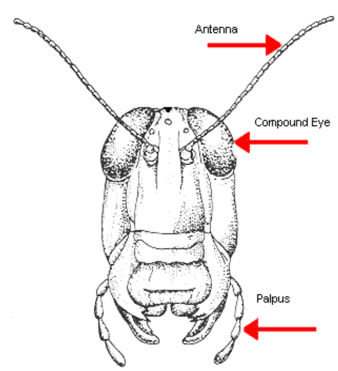
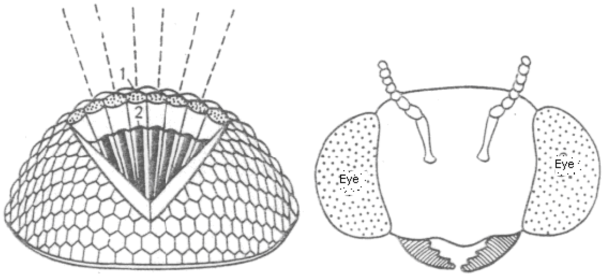


Fig. 17. Distribution of the insect eyes showing his location to optimize the angle of arrival of the light.

The ideal diameter of the optical small stick of the ommatidium is $d=f\Delta\alpha$, where f is the focal distance of the lens of the ommatidium. In this case, it is obtained the minimal possible narrowness of the field of vision of the ommatidium equal to $\Delta\alpha$, being maximum his sensibility to the light. It is necessary to construct the eye in such a way that when the punctual light source leaves the field of vision of an ommatidium, this source, immediately, should appear in the field of vision of an individual ommatidium [4].

Fig. 18. Fly's eye showing his location to optimize the angle of arrival of the light.



(a) (b)

Fig. 19. (a) Schematic cut of the compound eye of the insect: 1, Lens of the ommatidium; 2, Visual small stick of an unitary ommatidium. Lines of outlines indicate the directions of the optical axes of the neighboring ommatidium, (b) Disposition of the eyes in the insect's head.

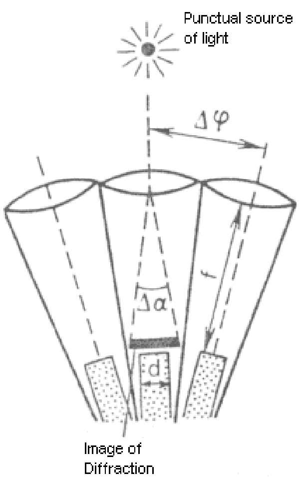


Fig. 20. Dimensions of the ommatidium of the compound eye.

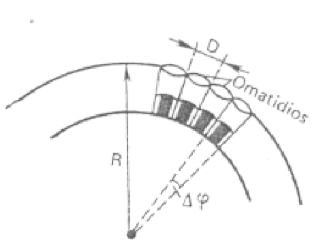


Fig. 21. Geometry of the ommatidium of the insect's eye.

IX. RESULTS

To take totally advantage of the reflections of the infrared beams for the wireless communications in closed enclosures (Figure 22), since every place, at which one is employed, changes his symmetry, it is necessary to take into account some aspects such as: the walls, roofs, or any other obstacle that presents this way to optimize the communications. It has been designed a software that allows to calculate the variations of the environment in different configurations, where an equipment of communication is installed. Using a program of channel simulation of the optical communications do not guided for infrared (Figures 24 and 25), and with an experimental accomplishment in the laboratory (Figures 27 and 28), data has been took, doing spatially incoherent the beam of the laser and taking measures of distance from the laser to the obstacle, where the beam is reflected [5],[6].

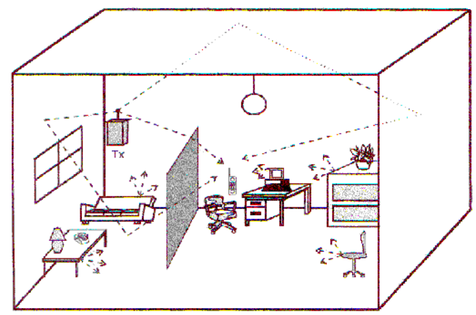


Fig. 22. Application of the spatial incoherence of the laser to the optical wireless communications indoor. Being located appropriatly the array of points inside the room will be able to optimize the transmission velocity of [7], [8].

Photoemmitters and photodetectors system were designed and constructed using hemispheres of *6 cm* of radio with spherical lenses of *2 cm* of radio and optical fibers of plastic of *5 mm* of diameter. It is thought that this is the ideal structure for transmission and reception when it is compared with an planar array with the same number of spherical lenses *(50)*, see Figure 26. The radius of the semisphere was calculated by the expression $Re = fD/d$, where D is the diameter of the spherical lens *(2.0 cm)*, d the diameter of the optical fiber *(0.5 cm)* and f is the focal distance of the spherical lens (*1.5 cm*), calculated with the expression $f = nR/2(n-1)$, being $n = 1.5$ the index of refraction of the glass and R the radio of the spherical lens $R = 1cm$(see Figure 23).

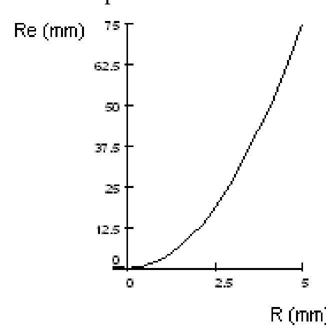


Fig. 23. Curve to determine the radius of the semisphere from the radius of the lens Re = Radius of the semisphere, R = Radius of the spherical lens, $n = 1.5$ is the index of refraction of the glass, $d = 1mm$ is the diameter of the optical fiber.

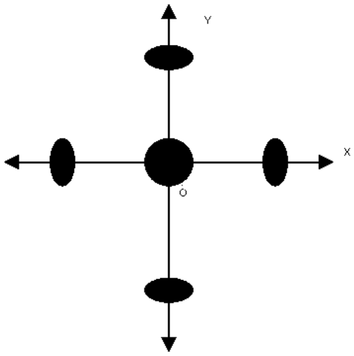


Fig. 24. Pattern Image of five analyzed points in the computational simulation.

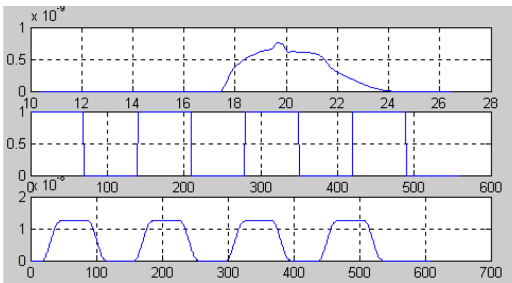


Fig. 25. Result of the computational simulation. In the top part it is observed the unitary impulse response, in the middle one the transmitted pulses and in the low one the pulses distortion.

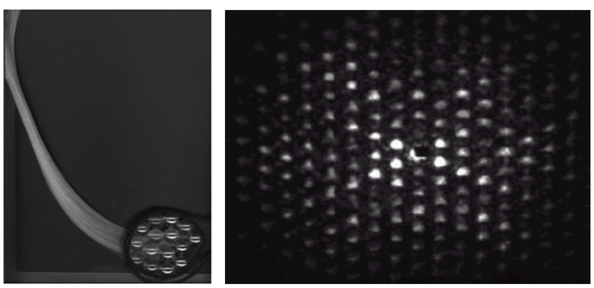


Fig. 26. Semispherical array of photoemmitters/photoreceivers simulating the insect's eye.

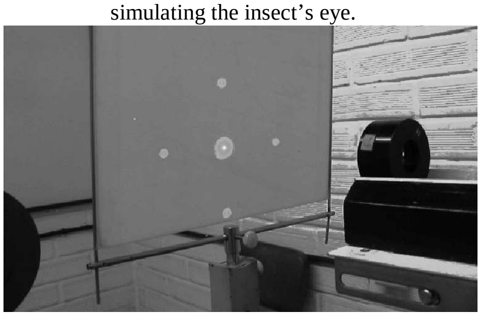


Fig. 27. Optical images for spatial incoherence of a laser in a photoemmitter of Free Space (FSO).

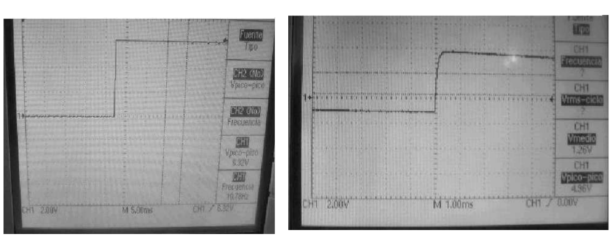


Fig. 28. Transmitted pulse and received pulse.

X. CONCLUSIONS

It has been presented a method for doing spatial incoherence of the laser's light, based on the concept of bionic and some results that will serve to optimize the bandwidth of the systems of optical communications. This opens the way of researches and developments of new technological applications of low cost. It is necessary to use a laser of average power to observe the images to long distances and lenses combined with optical fibers in order to be able to have a major incoherence, since a major number of them, major quantity of points they can be seen in the space. From these results a program of computational simulation, that allows to compare the theoretical values with the obtained ones experimentally has been elaborated. This one indicates that this is an original way for designing emitters and receivers of high performance for optical communications. The method that has been developed simplifies the calculations of the different parameters of the optical link, and allows to find the bandwidth of the channel, facilitating the design of links FSO in the access network across windows indoor.

ACKNOWLEDGMENTS

This work was partially financed by the University of Quindio, Colombia.

REFERENCES

[1] G. A. Stephens and S. A. Jaramillo Flórez,"The Last Mile Problem Solution using Free Space Optics", *Proceedings International Telecommunication Symposium - ITS2002*, Natal, RN, Brazil, Sept. 2002.

[2] G.983.1, "Passive Optical Networks for Broadband Access", *International Telecommunications Union*, Nov. 1998.

[3] S. A. Jaramillo Flórez, "Contribución a la Gestión de Nuevos Servicios por las Redes de Telecomunicación por Fibra Óptica en Colombia", *PhD. Thesis*, Universidad Politécnica de Madrid, Spain, 1999.

[4] K. Bogdánov, *El Físico visita al Biólogo*, Ed. MIR, Moscow, 1989

[5] S. A. Jaramillo Flórez, "Solución Biónica al Problema de la Red de Acceso de Último Kilómetro", *Proceedings Segundo Encuentro de Investigación, Innovación e Ingeniería en Telecomunicaciones*, CINTEL, Bogotá, Colombia, Agosto, 2005.

[6] S. A. Jaramillo Flórez, "Imágenes Ópticas por Descoherencia Espacial de un Láser en un Optrón de Espacio Libre", *Proceedings VIII Simposio de Tratamiento de Señales, Imágenes y Visión Artificial*, Medellín, Colombia, Nov. 2003.

[7] S. A. Jaramillo Flórez, "Caracterización Sistémica de Optrones de Fibra Óptica y de Espacio Libre", *Proceedings Primer Encuentro de Investigación e Ingeniería en Telecomunicaciones*, CINTEL, Bogotá, Colombia, Sept. 2003.

[8] S. A. Jaramillo Flórez, "Optimization of the Model for Optical Transmission Systems", *Proceedings XIV CBA2002*, Natal, RN, Brazil, Sept. 2002.