Integration of IR-UWB Signals into GPON FTTH networks

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***Abstract*—In the last years, FTTH (Fiber-to-the-home) networks became an excellent solution to deliver broadband internet access and TV services. A furthermore integration of IR-UWB (Impulse-radio ultra-wideband) signals into GPON (Gigabit-Passive-Optical-Network) technology is analyzed, with opportunity to allow wireless distribution of high definition video over a future personal area network. It is concluded that by using the modulation of same 1550 nm wavelength, IR-UWB multicast signals can coexist with the CATV (Community Antenna Television) analog signals and an easy adaptation of GPON communication systems is necessary to support this extension.**

Keywords—Fiber-to-the-home(FTTH) access networks; Impulse-radio ultra-wideband (IR-UWB); Community Antenna Television (CATV); Gigabit Passive Optical Network (GPON).

I. INTRODUCTION

Ultra-wideband (UWB) is a new radio technology, approved in 2002 by the Federal Communications Commission (FCC) for unlicensed use for a spectrum range from 3.1 GHz to 10.6 GHz [1]. Based on impulse transmission over this wide bandwidth, but at a very low power (less than −41.3 dBm/MHz), IR-UWB can provide high data rates, tolerance to multipath fading, low cost and low power consumption, making it the optimal technology for a wide variety of short-range applications, including indoor communications systems, security sensors and the future wireless personal area networks (WPAN) [2, 3]. In order to extend its application to delivery of high-definition (HD) audio-video content, without MPEG4/H264 coding and decoding, the using of UWB technology to transport such a large amount of data has been considered as an enabling solution, particularly within the context of the fiber-to-the-home (FTTH) access networks. The transmission of UWB signals over fiber is an excellent solution since they provide large bandwidth, a direct modulation of the UWB signal, no frequency up-conversion and then neither additional circuits for transmodulation [4].

II. TECHNOLOGYES REVIEW

A. IR-UWB wireless communications

IR-UWB (Impulse-Radio Ultra-wideband) is a wireless technology using a wide spectrum but at a very low power to transmit large amounts of digital data on a short distance. For example, a recent UWB transceiver implementation, using as pulse shape the 5th-order derivative of Gaussian signal, capable of delivery up to 2 Gbps has been reported [3]. With its large bandwidth, ultra wide band radio proves immunity to fading and the ability to carry signals into indoor spaces, through the doors and other obstacles that tend to reflect them.

UWB presents the unique characteristic of being designed for coexistence with other licensed or unlicensed services in the same frequency range. This is achieved limiting the equivalent isotropic radiated power (EIRP) density to −41.3 dBm/MHz and introducing detection-and-avoid (DAA) mechanisms. The spectral masks depend on applications and regions; in Europe and in Asian countries the regulations tend to be more strict while in the US and Canada they tend to be more relaxed, as is shown in Fig. 1 [2].

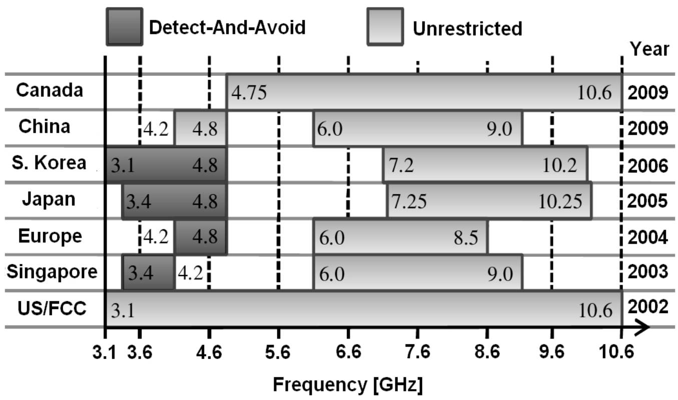

Fig. 1. UWB intended bands for communications for different regions [2]

B. FTTH optical fiber access networks

Passive optical networks PONs are widely considered to be the most promising cost-effective and high-performance solution for broadband access networks [4]. Fiber-to-the-home (FTTH) broadband access networks are being deployed on a large scale in Asia, United States and also in Europe to replace coaxial cable- or copper telephone wire-based access systems.

Two main FTTH-PON standards currently deployed are Ethernet passive optical network (EPON) (IEEE 802.3ah, 2004) and Gigabit passive optical network (GPON) (ITU-T G.984). The roadmap of communication system over PON network technology is presented in Fig. 2.

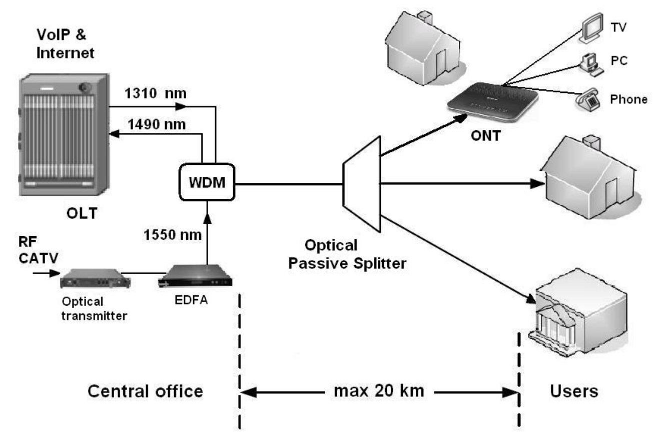

Fig. 2. GPON communication network

Both solutions cover distances of up to 20 km, use point-to-multipoint topology and time-division multiplexing (TDM) technology with variable split-ratio – commonly, from 32 to 64 users. There is no active equipment required in the field. PON architectures are cost-efficient compared with architectures including amplification and regeneration stages in the field [5].

Active transmission equipment in GPON network consists only of Optical Line Termination (OLT) and Optical Network Unit (ONU). Starting at the central office, only one single mode optical fiber strand runs to a passive optical power splitter near users' locations. At this point the splitting device simply divides the optical power into multiple separate paths to the subscribers. From the optical splitter, individual single-mode fiber strand run to each user (home, businesses, etc.).

This current standard PON is based on time-division multiple access (TDMA), but is expected to evolve toward PON based on wavelength division multiplexing (WDM-PON), that allows an individual wavelength for each user. At present, the main disadvantage of this new technology is the high cost of remote equipment as WDM demultiplexer and customer premise equipment laser. In Table I are synthesized the characteristics and performances of three PON standards.

TABLE I. PON STANDARDS

Parameters	PON Technologies		
	EPON	***GPON***	***WDM PON***
Download speed	1.2 Gbps	2.4 Gbps	1-10 Gbits/ Channel
Download wavelength	1550 nm	1490 and 1550 nm	Individual wavelength/ channel
Upload waveleghth	1310 nm	1310 nm	Individual wavelength/ channel
Traffic Modes	Ethernet	ATM Ethernet or TDM	Protocol Independent
Voice	VoIP	TDM/VoIP	Independent
Video	1550 nm overlay/IP	1550 nm overlay/IP	1550 nm overlay/IP

III. UWB SIGNALS INTEGRATION

The integration of UWB technology into the optical access network is possible into a very simple way: the electrical signal, instead to excite the antenna, is converted into optical domain and transmitted in their native format through the fiber network. At user location, an inverse conversion is done, the electrical signal obtained is fed to an antenna and furthermore radiated to the UWB receiver. This method is suitable for UWB communications because, even in the case of large spectrum of this signal, the bandwidth provided by FTTH networks is enough.

As a transparent implementation, the signal is transmitted in their impulsive format with no up-conversion. The UWB signals are emitted, photo-detected, filtered, amplified and radiated directly to establish the wireless connection. Hence, UWB radio-over-fiber is a rapid and cost-effective solution to deliver signals with high data-rate, for example a HD audio-video uncompressed stream (up to 1.65 Gbps) in FTTH access networks with further wireless PAN (WPAN) signal distribution at the home [6].

This paper analyzes an integration of IR-UWB multicast signal (downstream only), into existing GPON network, usually delivering data and CATV video content. The IP-data communication uses two wavelengths, 1310 nm for uploading and 1490 nm for downloading. To deliver HDTV contents over IR-UWB, it is proposed to use, as well as CATV distribution, the same 1550 nm wavelength, because apart spectrums of the two signal types, not interfering with each other, as is shown in Fig. 3. The idea of UWB and CATV over coaxial cable has been addressed by some studies [7], but in this paper is proposed a transmission of combined signal over fiber, with a schematic implementation presented in Fig. 4.

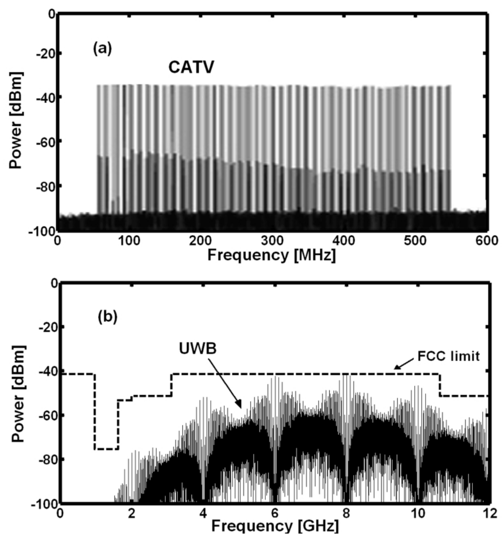

Fig. 3. CATV (a) and IR-UWB (b) RF spectrum

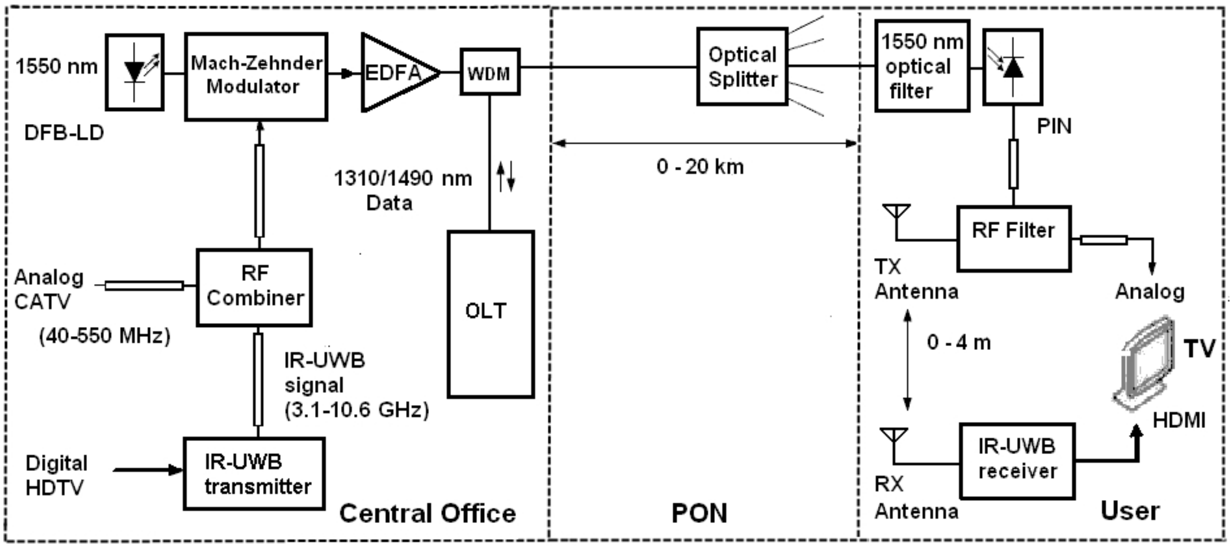

Fig. 4. CATV and HDTV -UWB overlay transmission into GPON system

Thus, the CATV RF signal is mixed with the UWB signal by a RF combiner. The resulting composed signal, applied to the optical transmitter, modulates the 1550 nm wavelength carrier generated by a DFB-LD (Distributed Feedback Laser Diode). The amplitude modulation is performed by a Mach-Zehnder modulator. The EDFA (Erbium Doped Laser Amplifier) increases the optical power of the signal, in order to compensate for the power losses occurred during the transmission and split [6], and handle the signal to a WDM (wavelength-division multiplexor), where is mixed with 1310 wavelength data-signal from OLT and injected into fiber cable.

The signal is transmitted through 0 to 20 km of fiber and after passing through the optical splitter, to the each one of the users. In the customers' premises, the optical signal filter is converted to the electrical domain by a positive-intrinsic-negative (PIN) photodetector, and the filtered UWB component is applied to the antenna. Over shorts indoor distances, the receiving antenna collects the radio impulses, provide them to the detector that delivers the digital video stream to the user.

The BER performance evaluation of 2 Gbps data-rate UWB transmission over 0-4 m wireless distance, without forward error correction (FEC) for a simple analysis, is shows in Fig. 5, in two cases [8]: back-to-back (B2B) optical emitter and receiver, or after 20 km propagation on single mode fiber.

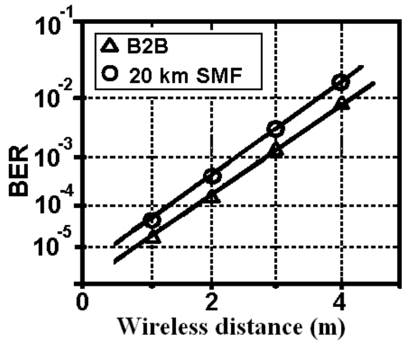

Fig. 5. BER performance of UWB transmission

IV. CONCLUSIONS

In this paper is analyzed a possible integration of IR-UWB multicasting signal in GPON standard FTTH networks. The use of same 1550 nm wavelength optical carrier with CATV broadcasting signal provides a low-cost and easy-to-implement solution to deliver high-definition video content. The way to combine and separate the two signals, suitable because of their separate spectrums, is done by a RF combiner and filter. respectively. An evaluation of the quality of received UWB signal is investigated, showing a viable simultaneous transmission of HDTV and analogue CATV signals over FTTH networks.

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