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Transmission of Voice, Video and Data in Fiber-To-The-Home (FTTH) Networks Using OFDM

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Abstract— **In this paper we have demonstrated a transmission system for triple play (voice, video, and data) with centralized orthogonal frequency division multiplexing-fiber to the home broadband passive optical network (OFDM-FTTH-BPON) based on an external modulator. At the one of two arms of system, voice and internet data are transmitted using Pseudo random binary sequence (PRBS) generator at bit rate of 1.25Gbps .In another arm of system, video is transmitted with the help of 4 QAM modulated OFDM signal. The 1.25Gbps voice signal, 1.25Gbps data signal and 10Gbps video signal have been transmitted over 20km single mode fiber (SMF) successfully.**

Keywords- Fiber to the home (FTTH); Passive optical network (PON); Broadband passive network (BPON); Orthogonal frequency division multiplexing (OFDM); Optical line terminal (OLT); Optical network unit (ONT)

I. INTRODUCTION

A. Fiber-to-the-home (FTTH)

FTTH networks are undergoing an increasing deployment rate in the recent years due to its bandwidth advantage and network transparency. FTTH access networks support the delivery of converged wired/wireless services on the same fiber. Fiber-to-the- home (FTTH) access networks are currently experiencing double-digit growth in Europe, several Asian countries and the United States as residential customers pursue faster connections for broadband and expanded services like internet data, video streaming, file sharing and various flavors of TV, including 3D, and high definition video conference [1]-[3]. In this scenario, in order to reduce costs and complexity, the development of a next generation of FTTH (NG-FTTH) networks that report the convergence and integration of optical-fixed and radio frequency (RF)-wireless is critical and is in evolution [4]–[7]. Additionally, NG-FTTH networks must consider techniques permitting optical and wireless transmission impairments compensation and network management, only executed at the central node. This implies efficient network architectures which can handle the deployment of a large number of services with different requirements, and where coexistence of optical-wired and RF wireless paths should be properly guaranteed [8]. Two techniques are currently being explored to cope with the pronounced demands: optical modulation formats and implementation of cost-effective transmitters. From the modulation formats point of view, orthogonal frequency division-multiplexing (OFDM) has been intended as a promising format to be used in NG-FTTH networks. In fact, one of the major advantages of this format is the fiber chromatic dispersion mitigation which has been specified as one of the major impairments enforced by the increasing distances required for NG-FTTH networks which are in the range from 20km to 100km and beyond [9]. OFDM radio signals seem to be an adequate choice for the distribution of RF-wireless applications in NG-FTTH networks [10]. The use of low-cost optical sources is critical in the development of NG-FTTH networks because the major investment of network terminal equipment is the cost associated with the transmitters at the optical network unit (ONU).

B. Broadband passive optical network (BPON)

The basic principle of PON is to share the central optical line terminal (OLT) and the feeder fiber over as many optical network units (ONUS) as is practical given cost effective optics. Since each ONU represents in some sense a customer or group of customers, this sharing helps to diminish the amount of network capital expense supported by each customer. This enables broadband fiber access in scenarios that up to now were unprofitable for traditional point-to-point or ring-based fiber architectures. A passive optical network (PON) is a point-to-multipoint, fiber to the premises network architecture in which unpowered optical splitters are used to enable a single optical fiber to serve multiple premises, typically 32-128. A PON configuration reduces the amount of fiber and central office equipment required compared with point to point architectures. The physical infrastructure of the B-PON uses a single fiber PON in most implementations.

II. THEORY OF OFDM

An OFDM System is a multi-carrier system which processes signals to be transmitted in parallel at different frequencies simultaneously from the same source. Conventional OFDM [11] system used IFFT and FFT to multiplex the signals in parallel with reduced complexity algorithm at the transmitter and receiver respectively. The system employs guard interval or cyclic prefix (CP) so that the delay spread of the channel becomes longer than the channel impulse response. The reason is to minimize inter-symbol interference between symbols.

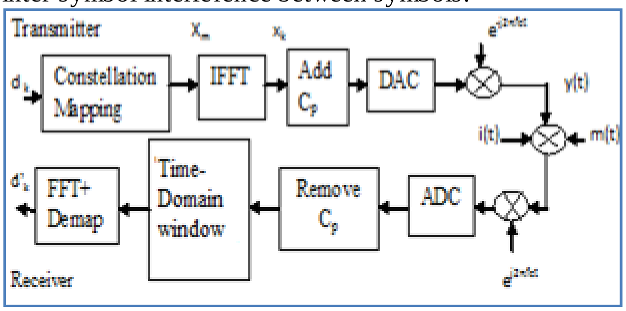

Figure1. OFDM transceiver.

A. Fourier-Based OFDM

In Fig.1, the data [d_k] is processed by M-ary QAM modulator to map the data before IFFT, with N subcarriers. Its

Output is the sum of the information signals in the discrete time bearing as following:

$$x_k = \frac{1}{\sqrt{N}} \sum_{m=0}^{N-1} X_m e^{\frac{i2km}{N}} \qquad (1)$$

Where (x_k /$0 \leq k \leq N-1$) is a sequence in the discrete time domain, (X_m /$0 \leq m \leq N-1$) are complex numbers in discrete frequency domain. The cyclic prefix (CP) is added before transmission to minimize the inter-symbol interference. At the receiver side, the process is reversed to obtain and decode the data. The CP is removed to obtain the data in discrete time domain. The data is then processed to the Time- Domain (TD) windowing for eliminating the narrowband interference before FFT. The output of FFT is the sum of the received signal in discrete frequency domain as follows:

$$X_m = \sum_{k=0}^{N-1} x_k e^{\frac{i2\pi km}{N}} \qquad (2)$$

B. OFDM PON

Orthogonal frequency division multiplexing (OFDM) radio signal have been recently proposed to deliver high definition audio and video contents to the end user through wireless broadcasting in short range environment. The existing access networks have become critical bottlenecks for fully utilizing the available core network bandwidths that provide the exponentially increasing end-users' demands for broadband services. Therefore, a great effort has been developed in order to create various techniques for enabling cost-effective, flexible and durable next-generation passive optical networks (PONs). Fiber chromatic dispersion has been indicated as one of the major impairments in PONs. To mitigate it, orthogonal frequency-division multiplexing (OFDM) signals in BPONs are transmitted [12].

III. SYSTEM MODELLING AND NUMERICAL MODEL

Design and deployment activities for FTTH (fiber-to-the-home) and FTTP (fiber-to-the-premises) access networks are on the rise in order to support the increasing demands and delivery of new multimedia services to the customer premises such as interactive video, voice, and high-speed Internet. There are many types of FTTH technologies; the most popular one is based on the concept of using a passive fiber distribution network, known as a passive optical network (PON). FTTH employing PON access architecture is the accepted choice of delivery channel for triple-play services (voice, video and data) from service providers to the home and business users. Three major PON technologies are currently under consideration as the basis for FTTH deployments: Broadband PON (BPON), Gigabit PON (GPON), and Ethernet PON (EPON). Broadband PON is the most mature and widely used among them to the date. BPON is a set of standards that specify the service capabilities and network protocols for broadband services over fiber access. In a PON, the active optoelectronics are situated on either ends of the passive network. An optical line termination (OLT) device is installed in the central office (CO), and an optical network termination (ONT) device is installed on the other end, in or near each home or business site. Fiber distribution is done using a tree-and-branch architecture. A single fiber connected to the OLT can be split up to 32 times and connected to multiple ONTs. Current simulation models a typical BPON FTTH design with 32 subscribers and 20-km reach as shown in Fig. 2. The Central Office is connected through a 15-km standard single mode fiber to the first Remote Node with a 1:4 splitter. Each of the four outputs goes through another 4.5-km fiber and then enters the Remote Node with a 1:8 splitter. Outputs from the 1:8 splitters are connected to eight end-users at the ONT though drop-off cables of length varying from 100 to 900 feet. The triple-play service is realized as a combination of data, voice, and video signals. To optimize the bandwidth in BPON the transmission through the optical fiber path employs the CWDM technique with data and voice component transmitted at wavelengths in the range of 1480-1500 nm, and video within the 1550-1560 nm range. The high-speed internet component is represented by a data link with 1.25Gbps downstream bandwidth. The voice component can be represented as VOIP service (voice over IP, packet-switched protocol), which is gaining popularity as an alternative to traditional PSTN (public switched telephone network) with POTS (plain old telephone service) at the customer end. Figure 3 shows the signal spectrum output from OLT with data/voice signal at 1500 nm and video signal at 1550 nm. For video transmission, system is composed of three main blocks OFDM transmitter, optical path and OFDM receiver. Linear standard single mode fiber transmission is considered as usually occurs for typical distances of FTTH networks. The generated OFDM signal has 8 sub carrier. The OFDM transmitter consists in the symbol mapping, IFFT block, Bessel LPF with a -3db bandwidth of 4MHz. QAM is used as modulation format of information subcarrier. The OFDM signal bit rate is 10Gbps and its bandwidth is 10 GHz. A CW laser is used in optical path as optical transmitter. A SSMF dispersion parameter of 16ps $nm^{-1}km^{-1}$ is considered. At the optical receiver, a super Gaussian filter is with a -3db bandwidth of 100GHz and PIN photodiodes are used to reduce the optical noise power and to photo detect the optical signal respectively. In the receiver the signal is filtered by Bessel LPF.

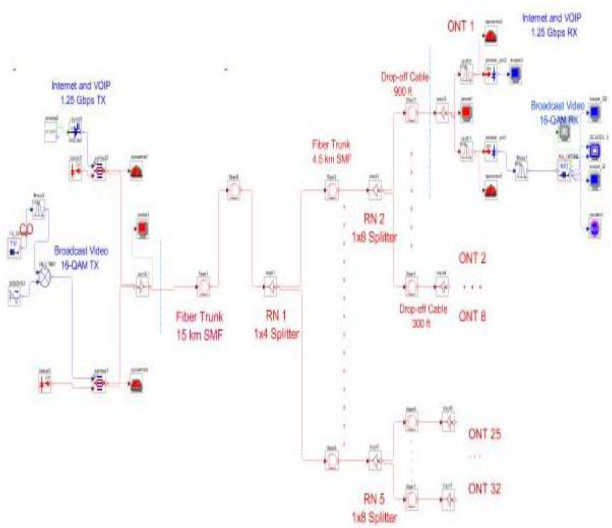

Figure2. Schematic of FTTH-BPON system

The received OFDM symbols are then obtained after FFT demodulation. The signal from the central office travels through a 20-km long fiber distribution network and arrives at optical network termination unit. Figure 2 depicts the system setup used to describe the distribution of voice, video and data in FTTH-BPON network. For transmission of voice and data signal, PRBS generator and an external modulator is used. CW laser is used in optical path as optical transmission. Both voice and data are transmitted at 1.25Gbps by single arrangement. Video is transmitted at 10Gbps.

IV. RESULTS & DISCUSSION

The optical spectrum at the input to ONT is shown at Figure1. Here the optical signal first de-multiplexed into data/voice and video components. The data goes to the optical PIN type receiver. Optical power meters inserted after transmitters and before receivers show that total attenuation from fiber spans and splitters is about 29 dB and input power to the receiver is about –25 dBm in case of voice and data and 1.6dBm in case of video. The receiver eye diagram for voice/data and video signals is given in Fig. 4 and in Fig. 5 respectively. The video component of the received signal enters at OFDM receiver. Electrical spectrum, frequency spectrum and scattering are analyzed at receiver.

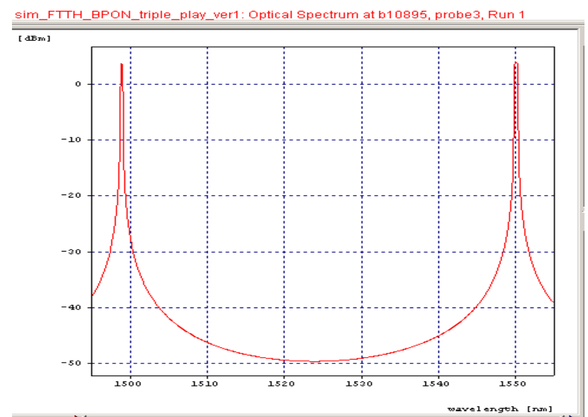

Figure3. Output spectrum from Central Office

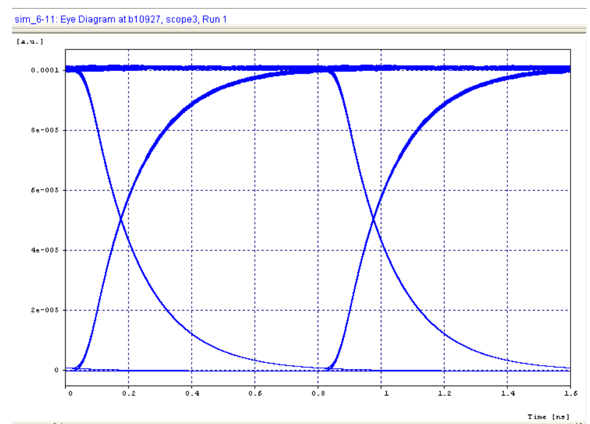

Figure4. Received eye diagram for voice and data signal

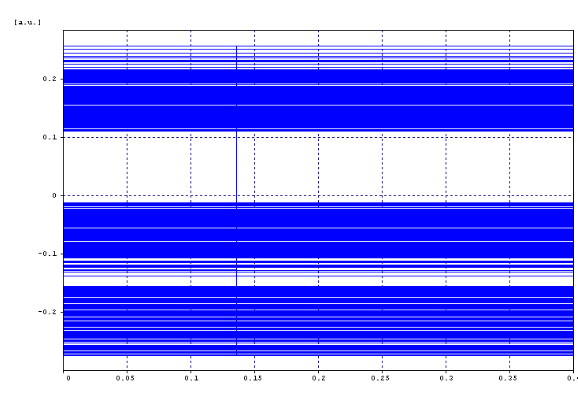

Figure5. Received eye diagram for video signal

Eye opening is 0.122979 a.u in transmitting video signal and achieved BER is 10-3 dB and jitter is 0ns.

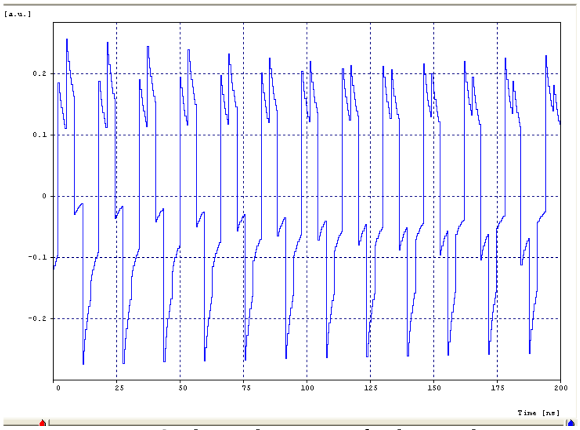

Figure6. Electrical spectrum of video signal

Electrical spectrum shows maximum amplitude of electrical signal is 0.529014 a.u.

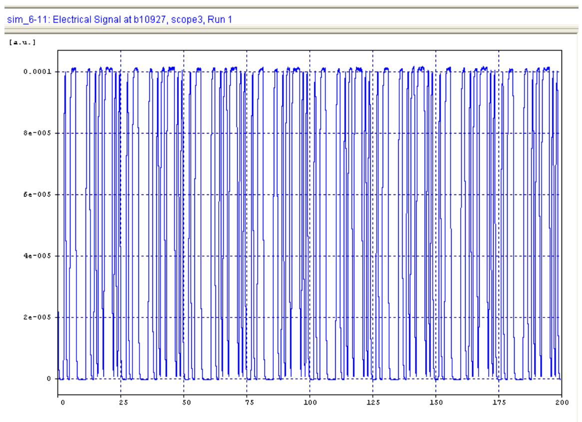

Figure7. Electrical spectrum of voice and data signal

Maximum amplitude of received electrical signal is 0.00010a.u in transmission of voice and data signal Corresponding power which is -73 dB.

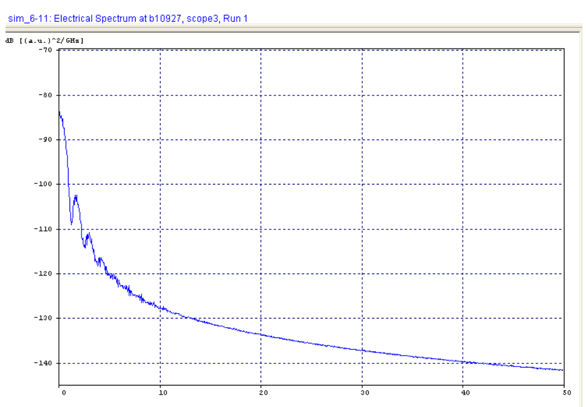

Fig. 8 shows maximum frequency of reception and maximum

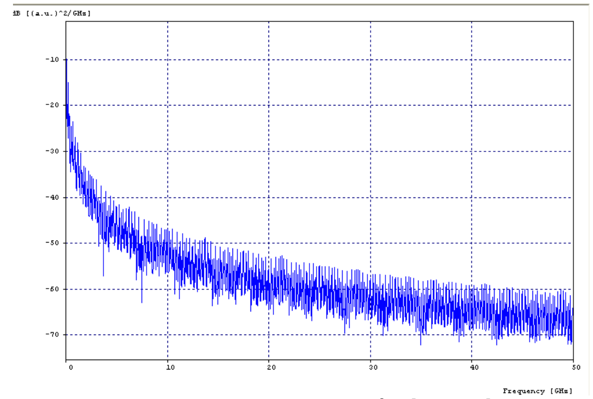

Figure9. Frequency spectrum of video signal

Frequency spectrum depicts maximum allowable frequency and corresponding power in dB. Maximum power is -5.20806 dB.

V. CONCLUSION

A transmission system is established for triple play (voice, video and data) with centralized OFDM-FTTH-BPON based on an external modulator. We have Transmitted voice and internet data by using PRBS generator at the data rate of 1.25Gbps at a BER of 1×10-40 and video is transmitted with the help of 4 QAM modulated OFDM signal at the data rate of 10Gbps at a BER of 1×10-3. The 1.25Gbps voice signal, 1.25Gbps data signal and 10Gbps video signal have been transmitted over 20km single mode fiber (SMF) successfully in a FTTH network.

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