INCREASING OF THE CATV SYSTEM CAPACITY

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Keywords – interactive channels, segmentation, frequency shifted, DWDM

In this paper are described several strategies for increasing of the CATV systems capacity. Estimation of the effectiveness of usage of QAM and PSK modulation techniques in upstream and downstream interactive channels is performed. The results of space segmentation of the network and up converting of the signals in the upstream channels are analyzed. Furthermore, the application of DWDM technology in the CATV systems and the requirements to its optical components are emphasized.

1. INTRODUCTION

In the CATV systems the frequency channels are comparatively wideband (7 or 8 MHZ) and this allows the service providers to deliver many additional services besides satellite and terrestrial TV and radio channels. These services include special channels (sport, news, education, weather, business, games and etc.), paid TV channels and packet of services that includes Internet access, security services, data transfer and phone services in the local area.

Additional services demand imposed the CATV distribution system to become two-way by introducing of the uplink (from subscribers to the head-end). In order to have access to these additional services the subscribers must have adapters, for example, STB (Set-top Box) for digital TV channels and cable modems for the Internet access.

In the CATV systems the carrying of the signals is realized by a modulation of separate carriers, hence, Frequency Division Multiplexing (FDM) is performed. For a transmitting of analog signals frequency band from 110 to 450 MHz is used and for digital – from 450 to 860 MHz. In Bulgaria the channel bandwidth of 8 MHz is approved. In the greatly narrower uplink band that is from 5 to 65 MHz only digital signals are transmitted.

2. TECHNIQUES USED FOR FORMING OF UPSTREAM AND DOWNSTREAM CHANNELS

In order to increase the CATV system capacity the analog channels should be replaced by digital. Furthermore, the modulation technique used for transmitting of the digital channels is selected in order to provide maximum system capacity. Transmitting of digital radio and TV channels by standard analog bandwidth of 8 MHz requires a compression to be used before modulation. Very often MPEG-2 is used as compression method and in this case simultaneously are transmitted several digital TV channels by one physical channel (8 MHz).

Capacity of the digital communication systems is increased proportional to the spectral efficiency of the modulation technique that is used. When M-ary modulation technique of higher order is used then both the spectral efficiency and the bit rate are increased but in turn the noise immunity of the signals is decreased. These contradictious requirements have to be taken into account when modulation technique is selected for upstream and downstream channels in the CATV systems.

Figure of merit for downlink is the bit rate (system capacity). Therefore, it is imposed 64QAM and 256QAM techniques with spectral efficiency of 6bit/s/Hz and 8 bit/s/Hz, respectively. If 64QAM is used in 8 MHz wide frequency channel then theoretical bit rate is 48 Mbit/s but as a result of the additional signal processing (compression, encoding) the bit rate is reduced to 40 Mbit/s. In the case when 256QAM is used for downstream channels then the bit rate reach to 56 Mbit/s. The capacity of an entirely digital system with 8 MHz channel spacing reaches to 3,7 Gbit/s (for 64QAM) and 5,2 Gbit/s (for 256QAM).

There are conditions for penetration of a noise and interferences in the uplink. Due to the figure of merit in the uplink is the noise immunity of the signals. Therefore, very often QPSK and 16QAM modulation techniques are used in the uplink. Small spectral efficiency and great noise immunity are inherent to these techniques. Overall capacity of uplink varies from 45 to 60 Mbit/s (for QPSK) and from 90 to 120 Mbit/s (for 16QAM).

Digital channels are divided in two groups – broadcasting (common access) video channels and interactive service channels. The second group of channels is dedicated to interactive services as Internet access, VoIP and video on demand. The capacity of these channels is distributed between different subscribers through the usage of TDM. The capacity of upstream channels (50-100 Mbit/s) is shared between subscribers connected to one optical node. In deed, the subscriber access to the upstream channels is provided by the TDMA technology.

3. SPACE SEGMENTATION OF THE CATV SYSTEM

New generation of CATV systems are the hybrid fiber/coax (HFC) distribution systems that consist of optical rings with additional Hubs included along the rings (Fig.1). The signals are conveyed from the Hubs to the nodes over the optical fibers. In the nodes the optical signals are transformed into electrical. After that the signals are distributed to the subscribers by coaxial distribution system that has capacity for 500 to 2000 subscribers. Hence, previously built coaxial distribution systems were combined through the usage of optical rings and in this way the subscriber service was localized in one head end.

Space segmentation of the HFC systems allows a reuse of the frequency bands that are allocated for downlink and uplink. This fact is owing to that all subscribers connected to the optical node have access to all frequency resources of the system.

However, only parts of them are subscribed to the additional services and they can be grouped in one or more cable segments (CS) of the distribution system. Usually, in one CS are included from 100 to 150 subscribers but there is a trend their number to be decreased to 30-35. In every subscriber group (or CS) is allocated one or more interactive upstream channels.

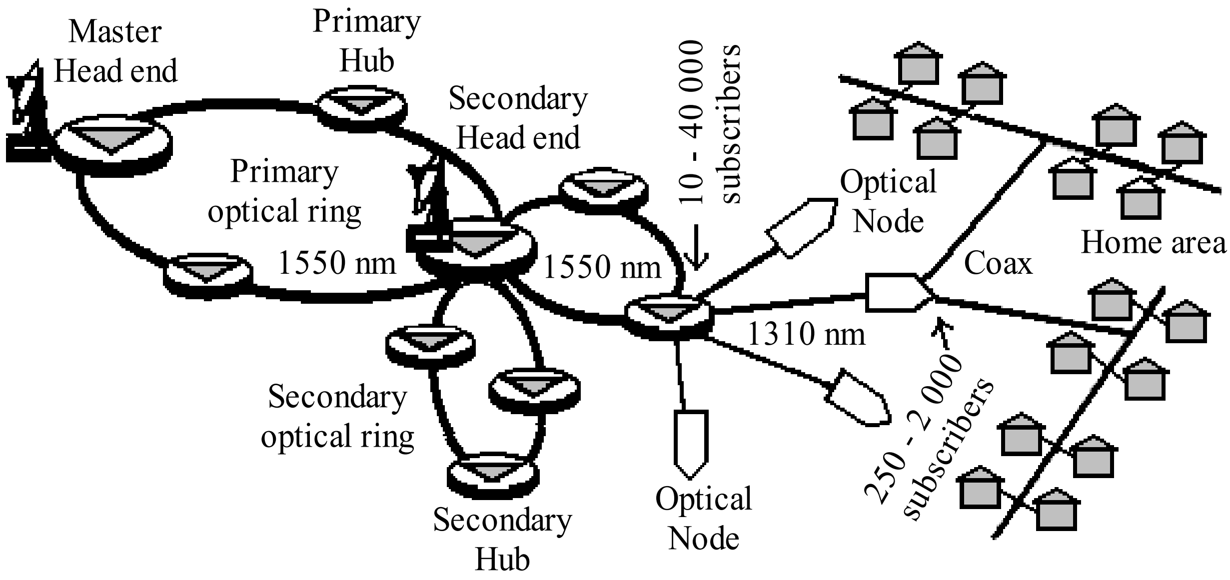

Fig.1. HFC system topology

For example, if one interactive downstream channel accommodates 100 users and it is 8 MHz wide and 64QAM technique is used then every user has a capacity of 400 kbit/s. In order to be achieved higher bit rates and great volume of data to be transferred to the users, respectively, it is necessary to be increased the number of the shared interactive downstream channels. For instance, when the number of interactive channels is two at the same initial condition the bit rate is doubled. Also, this effect is observed when these 100 subscribers are divided in two CS. In every segment one interactive channel is dedicated for the additional services.

4. INCREASING OF THE UPLINK CAPACITY

In the common case, every node in the HFC systems has four outputs for the connection to the coaxial lines. The frequency band of uplink is jointly used from all subscribers. Hence, subscribers have a small amount of overall system capacity. In order to be increased the uplink capacity it should be used more transmitters in the nodes. For example, if the number of the transmitters is N then the uplink band will be shared between N times fewer subscribers. In this case to every subscriber will be available N times greater capacity. In deed, this approach is unprofitable due to the building of N optical links that are required. Every optical link includes optical transmitter, fiber and receiver.

The parallel usage of the uplink band from several cable segments (CS) can be easily achieved by the converting of subscribers RF signals in another higher band. The uplink in this case is shown on Fig.2. Such topology provides access of four CS to the all uplink band.

The signals from the four cable segments of the coaxial distribution system are shifted up by the up-converter to frequency band from 112 to 400 MHz. In this way the uplink capacity is increased four times. After detection in the optical receiver the group signal is fed to a down converter that translates each of the upstream channels in their original band from 5 to 65 MHz.

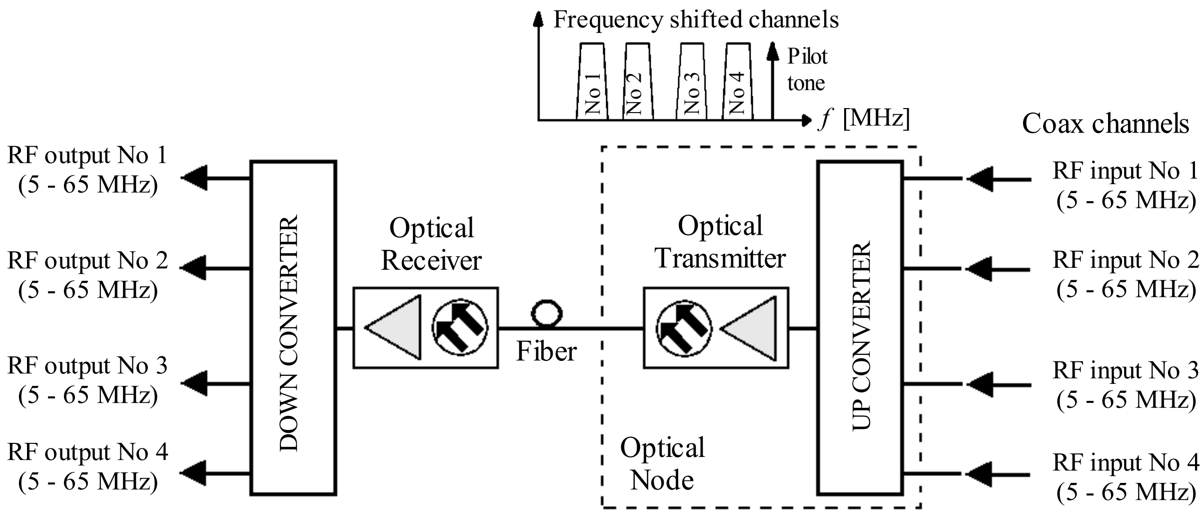

Fig.2 Technique used for an increasing of the uplink capacity

Pilot signal is added to the group signal and it has two very important purposes. First, it is used as a control signal for the circuitries of Automatic Gain Control (AGC) due to the pilot signal level depends of the losses in the uplink. Also, this pilot signal is necessary for the correct work of the PLL circuitry of the down converters in the head end.

5. USAGE OF THE DWDM IN THE CATV SYSTEMS

CATV system capacity can be significantly increased by the usage of the Wave Division Multiplex (WDM) technology or Dense Wave Division Multiplex (DWDM) technology, respectively. These technologies allow multiple usage of the frequency band allocated for the interactive upstream and downstream channels. For this purpose it is used several optical carriers with different wavelength that are transmitted over one fiber. In such way it is achieved an increasing of the frequency band shared between the subscribers for interactive downstream and upstream channels. The DWDM technology was imposed for wavelengths about 1550 nm (from 1530 to 1570 nm). The wavelength of the optical carrier is selected in accordance to the ITU wavelength grid. The step of this grid is 0,8 nm (100 GHz) but in the CATV systems it is selected greater step that is very often 200 or 400 GHz. By the usage of DWDM already is achieved a system capacity over 1 Tbit/s.

The principles of building the universal DWDM multimedia CATV system are shown on Fig.3. Typical feature of this topology is that the interactive downstream channels are transmitted from head end to the hub over one fiber by the usage of DWDM technology. The same technology is used for multiplexing of the upstream channels that are allocated to different cable segments. Very special feature of the shown above topology is that the adding of the common access (VSB-AM) and interactive (QAM) channels is performed in the optical range.

RF signals of the analog channels (VSB-AM) modulates optical carrier with wavelength λ_9 (about 1550 nm) that are transmitted through the fiber to the nodes. For this purpose in the head end is included optical transmitter that comprises both Distributed Feedback Laser (DFB laser) and Mach-Zender modulator. In order to be transmitted the QAM signals for the interactive subscribers service it is used eight wavelengths ($\lambda_1 \ldots \lambda_8$) that are selected from ITU standard grid and they are combined in one fiber by DWDM multiplexer.

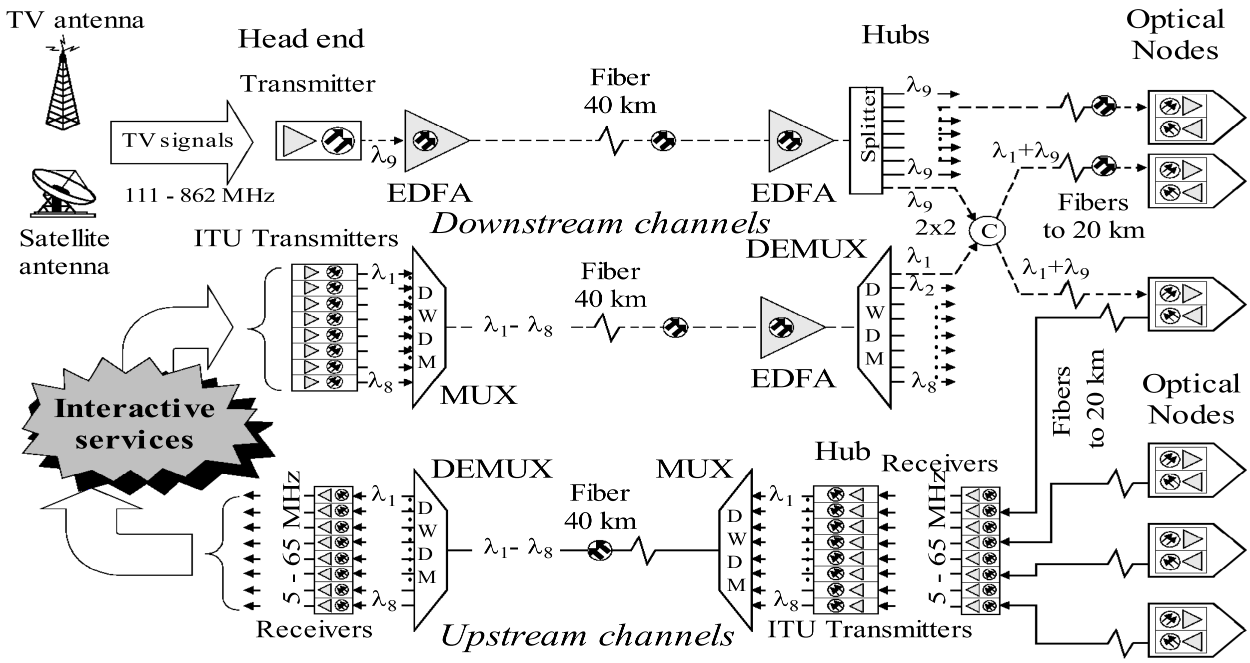

Fig.3. Universal DWDM topology for a CATV system

The optical fiber between the head end and the hub is about 40 km long. It is used a single-mode fiber NZ-DSF type that has minimum losses and dispersion in the optical range about 1550 nm. The fiber losses are compensated by the means of type EDFA (Erbium Doped Fiber Amplifiers) optical amplifiers with compression point from 17 dBm. In the hub the optical signal for the analog channels is divided in eight and is added to each optical carrier that are allocated for the interactive services. Output complex signal from each adder is divided between several nodes that use one and the same wavelength. In this way the usage of the DWDM provides eight times growth of available frequency band for the downstream interactive channel.

Optical node consists a receiver that detects VSB-AM and 64QAM (256QAM) signals and distributes them to the RF devices in the coaxial distribution system. Furthermore, in the node is included an optical transmitter for upstream channels. In the topology that is considered the DFB laser transmitter works with 1310 nm wavelength. Signals from subscriber cable modems are multiplexed and after that they perform QPSK or 16QAM modulation of the optical carrier. The transmitter and the receiver in the node are connected to the hub by separate SMF fiber 20 km long.

6. CONCLUSIONS

In this paper are given selection criteria of the techniques used in the downstream and upstream channels in the CATV system. These criteria are related to the system capacity and the noise immunity. It is proposed an approach for increasing of the uplink system capacity through the usage of up converting of the signals incoming to the four node inputs to the band from 112 to 400 MHz. DWDM system topology with eight independent optical links for interactive channels is represented. If the technique for the increasing of the uplink system capacity is used in such DWDM topology it could be provided simultaneous transmission of the upstream data through 32 independent channels.

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