

## RF FRONT-END OF CATV MODEM

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*In this paper is described the connection of the CATV system to the Internet and the method of working of this complex system. A block diagram of RF front-end of the cable modem with triple frequency conversion of the CMTS signals is proposed. In the downlink channel of this modem is used infradyne tuner and the third IF is equal to the symbol rate. Therefore, digital signal processing is possible, such as detection, filtering and decoding. The cable modem incorporates frequency agile modulator to generate the upstream signal. MAC message send by CMTS is used to form the control signals for the adjustment of the upstream channel carrier.*

### 1. INTRODUCTION

Optical and digital technologies that were introduced in the CATV systems allow cable TV providers to include additional services as high speed Internet access. Furthermore, if the Internet access is realized by the usage of 8 MHz wide frequency channel then it can be achieved bit rates that are many times greater than 56 Kbit/s rates inherent to the dial-up modems. For example, let we assume that 64/256 QAM technique is used then the bit rate is 41,4/55,2 Mbit/s. Unfortunately, at the present time the frequency channel is shared between 100 subscribers due to the maximum capacity that can be provided to each of them is 512Kbit/s. There is a trend this subscriber number to be reduced to 30-35 that would be result in bit rates greater than 1 Mbit/s.

Two-way transmission of the Internet traffic is performed by the Cable Modem Transmission System (CMTS) that is located in the head-end or the hub. Cable Modem (CM) is used in order to receive the data packets addressed to the subscriber and to transmit the data to the CMTS. The CM consists of two main units – the RF front-end and the control unit. The recommendations intended to the MAC and the Physical layer of the interface between the CMTS and the CM are comprised by the standard DOCSIS.

There are two main problems when Internet access is performed over CATV system. First is related to the control of the access to the frequency channels allocated for interactive services, especially the upstream channels. Second problem is so called funnel effect. This effect is related to the accumulation of the noise and the interferences from the uplink in the head-end. Hence, it can result in a breakdown of the Internet service. This problem usually is resolved by the space segmentation of the coaxial distribution system and the transition to entirely passive optical system.

## 2. IMPLEMENTATION OF THE CATV SYSTEM WITH INTERNET ACCESS CAPABILITY

Simple block diagram of CATV system with capability for Internet access is shown on Fig.1. The data packets are conveyed to and from Internet (or other external networks) by the usage of router. Further, CMTS is used for both a transmission of these data packets to the cable modems of the subscribers and a reception of the IP data carried by the upstream channels. In the head-end are located several servers, FDDI switchers, firewalls that control access to and from the server complex and a monitoring station.

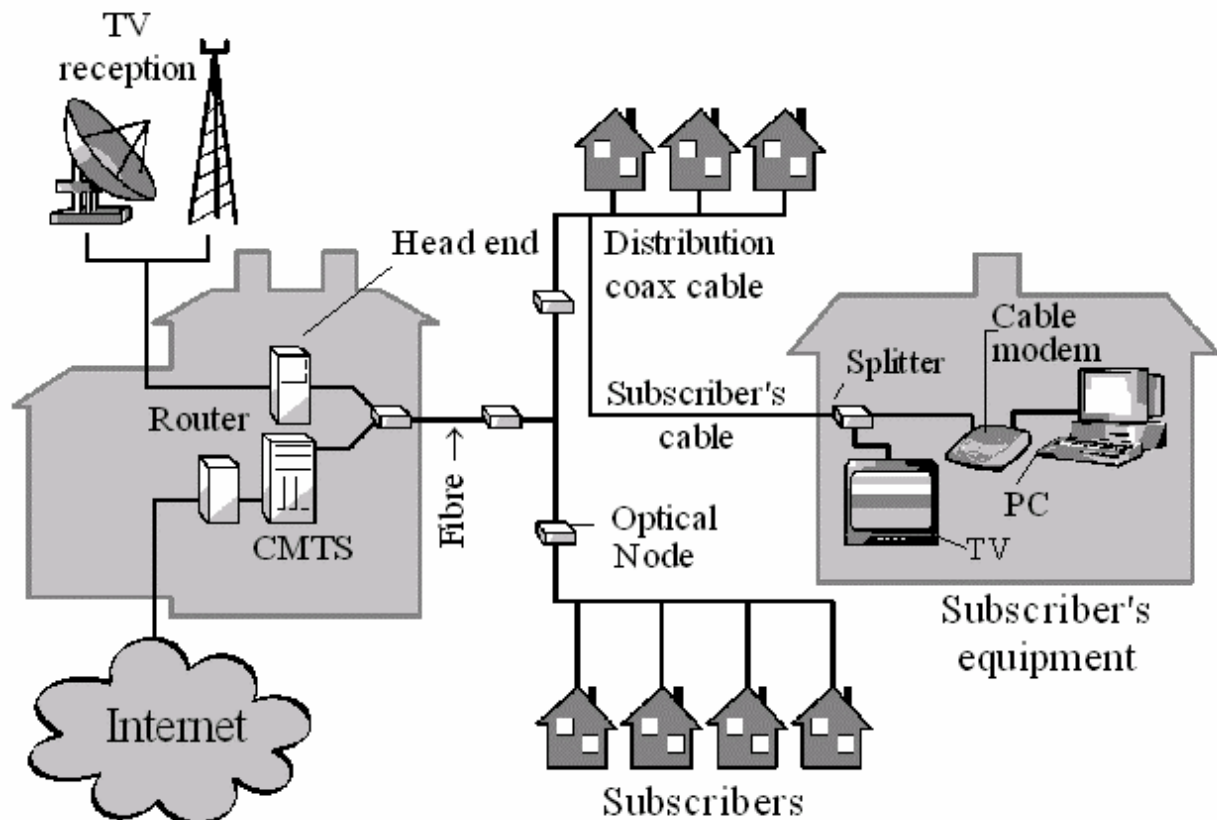


Fig.1. Topology of the CATV system with Internet access capability

DOCSIS standard recommendations intended to the upstream and downstream radio interface are given on Fig.2. The interface between the Internet network and the CMTS is so called Network-Side Interface (NSI) that provides data rates of 100 Mbit/s (100Base-T). Every downstream channel is formed by separate QAM transmitter and it is dedicated to a given subscribers group. Jointly usage of a given downstream channel requires Time Domain Multiplex (TDM) technology to be used for data, video and audio signals that are transmitted to the subscribers in the group.

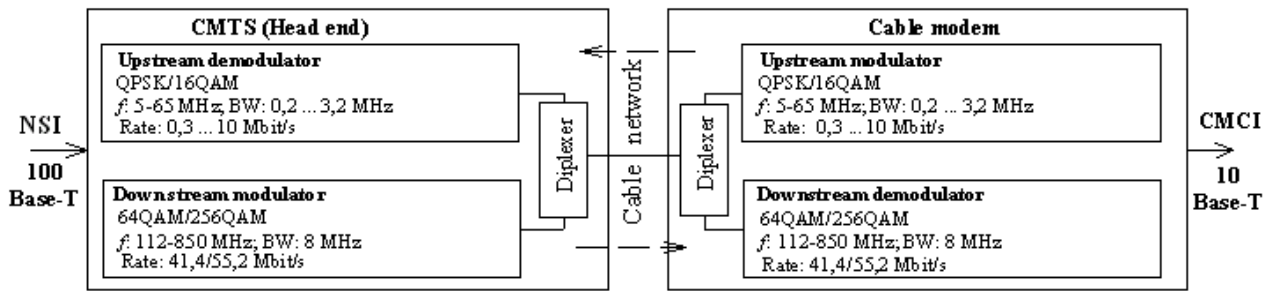


Fig. 2. Recommendation to the radio interface between CMTS and CM

In the cable modem receiver is performed signal processing of the 64/256QAM signals: demodulation, filtering and decoding. After, the data packets addressed to the subscribers are distributed. For this purpose in the DOCSIS standard is foreseen 10Base-T (10 Mbit/s) Cable Modem Customer Interface (CMCI). In the uplink, transmission of the QPSK/16QAM signals from the subscribers in one group is performed through the usage of the TDMA technology. In the CMTS for every upstream channel is dedicated a receiver that process the signals from the subscribers in one group.

### 3. DOCSIS PROTOCOL FOR THE COMMUNICATION BETWEEN CMTS AND CM

First, we examine the power-up sequence of the DOCSIS protocol. When CM is turned on it begins to scan the downstream channels and it attempts to make synchronization to the CMTS by such a channel. After successful synchronization CM receives the parameters of the upstream channel that is allocated to it and send request to the CMTS for Internet access. On the other hand, CMTS sends to CM configuration information about time slots allocation (usually three successive slots) that CM can use to adjust its transmit timing (clock generator) and information about CM acceptable transmit power level. These adjustments are imposed due to that the subscribers' CM are located at different distances from the head-end and this results in unacceptable differences in the upstream signals losses and delays. The Cable Modem (CM) uses only the second time slot for a transmission. Another two time slots are foreseen in the standard in order to avoid collisions with the other subscriber's signals.

After power-up sequence the CM is registered in the CMTS that dedicates to it an upstream channel and time slots for a data transmission. The duration of the time slot in the upstream channel is 1ms or 2,5ms. Due to the burst mode transmission in the uplink the demodulator in the CMTS is needed some time for its put in action. For this purpose a unique word is included in the packet before the data. Also, this word provides additional synchronization of the demodulator during the reception of the burst. It is important to be mentioned that the CMTS can change the upstream channel at any time in order to be avoided errors owing to unacceptable noises and interferences in this frequency band. In order to be registered in the CMTS CM must

hold specific 48-bit MAC (Media Access Control) address that is written in the device from the manufacturer.

#### 4. BLOCK DIAGRAM OF THE CABLE MODEM

Block diagram of the proposed Cable Modem (CM) is shown on Fig.3. The receiver is infradyne with triple frequency conversion of the CMTS signals and the third IF is equal to the symbol rate  $F_{sym}$ , i.e.  $f_{i3} = F_{sym} = 6,952 \text{ MS/s}$  (3a 64/256 QAM). Such a decision allows reducing of the interferences in the downstream channels, usage of digital signal processing (demodulation, filtration and decoding) and a possibility of implementation of the modem in a single IC. In the CM transmitter front-end are included the both frequency agile modulator that generates the upstream signal and an adjustable amplifier used for a setting-up of the required output power level. The modem control is performed in accordance to CMTS instructions by the usage of an embedded processor.

In the RF tuner is realized a selection of the downstream channel that is intended to the subscriber and a conversion of the signal spectrum in first and second intermediate frequency (IF) band ( $f_{i1} = 1100 \text{ MHz}$ , a  $f_{i2} = 36,125 \text{ MHz}$ ). The first IF  $f_{i1}$  is taking out over the maximum downstream channel frequency (860 MHz) in order to be decreased the VCO coverage factor ( $k_{f(h)} \approx 2$ ) and the intermodulation products to be outside the operating frequency band of the system. RF tuner output signal is processed by Surface Acoustic Wave (SAW) filter with bandwidth of 8MHz and then it is fed to down-converter for the third frequency conversion. The third heterodyne is Voltage-Controlled Oscillator (VCO) with phase synchronization to the carrier recovery block in the QAM demodulator.

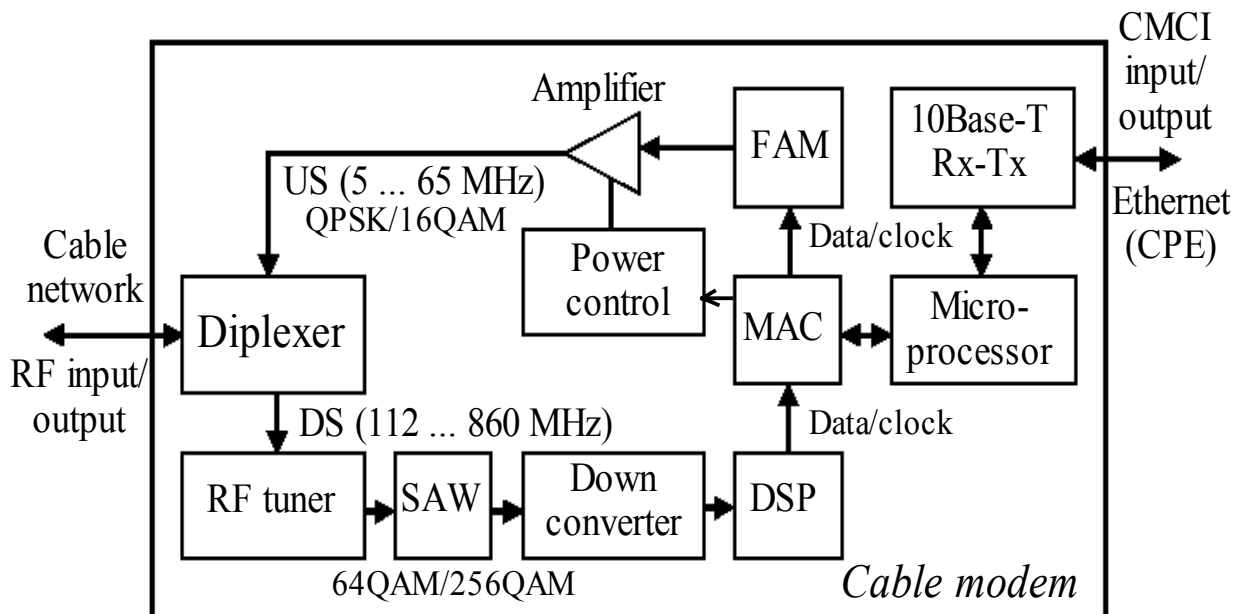


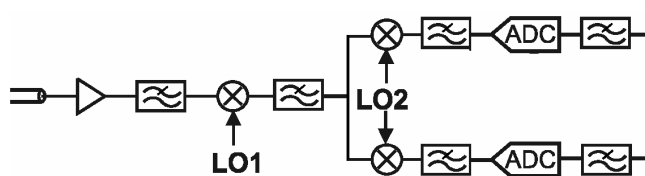
Fig.3 Block diagram of the Cable Modem

Due to the usage of a digital signal processing of the third IF signal it is required the analog signal to be converted into digital. For this purpose it is used Analog-to-Digital Converter with resolution of 8bits for 64QAM and 9bits for 256QAM signals. Sample frequency usually is equal to  $4F_{sym}$  and it is synchronized to the data clock recovery circuitry in the QAM demodulator. The demodulated digital signal passes through the Nyquist filter and then it is converted into form that is suitable for implementation of Forward Error Correction (usually 8-bit parallel code). In the QAM demodulator is formed the voltage used for Automatic Gain Control (AGC). This voltage is fed to the RF and IF amplifiers in the tuner in order to be increased its dynamic range. Also, in the QAM demodulator are recovered the IF carrier and the data clock. The mentioned above functions are implemented by the usage of a Digital Signal Processor (DSP).

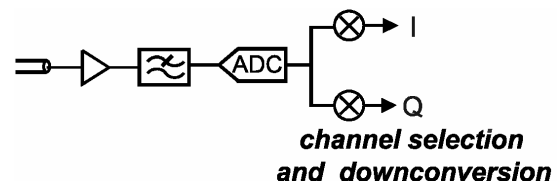
The block Media Access Control (MAC) separates the received MAC message from the remained data that is represented in Ethernet format and is fed to the Customer-Premise Equipment (CPE) – very often PC. The MAC message is used in order to adjust both the carrier of the Frequency Agile Modulator (FAM) and the CM output power level.

## 5. IC IMPLEMENTATION OF THE CABLE MODEM FRONT-END

Integrated Circuits (IC) implementation of the proposed CM front-end is getting more complicated due to the super-heterodyne receiver that is used. Adjacent channel selectivity of this receiver can not be achieved when IC resonators are used due to inherently to them very small quality factor  $Q$ . It imposes the usage of other receiver conceptions that are depicted on Fig.4 and Fig.5.



Фиг.4. Zero-IF receiver



Фиг. 5. All digital front-end

A first alternative is to use a “zero-IF” architecture with an analog quadrature downconversion mixer. Such a quadrature mixer consists of two identical mixers, driven by local oscillator signals that have a 90-degree phase shift with respect to each other. Quadrature downconversion eliminates the mirror signal problem of a classical heterodyne downconversion and thus also eliminates the need for a mirror suppression bandpass filter. Channel selection filtering can now be performed at baseband, either in the analog domain or in the digital domain. In this case the IF filter does not have to be very steep and could be integrated. The zero-IF receiver of Fig. 4 uses a double conversion architecture. First there is an upconversion to a fixed IF frequency and next – the quadrature downconversion to baseband.

An alternative version of the zero-IF topology could be a direct downconversion of the RF signal to baseband (Fig. 5). In this front-end architecture the complete RF band is converted to the digital domain with a high-speed high-resolution analog to digital converter. The complete front-end functionality (channel selection and downconversion to baseband) is then implemented in the digital domain. In such architecture however the quadrature local oscillator signal has to be tunable over a relatively wide range.

A corresponding circuit realizations the above described principles are given in [2] and [3]. They comprise analogue and digital anti-aliasing filters, sigma-delta modulator, digital frequency converter and decimation filter and can be built in a single CMOS IC.

## 6. CONCLUSIONS

The proposed CM front-end was tested in order to determine acceptable level of the interferences in the uplink and downlink that ensure given Bit Error Ratio ( $BER \leq 10^{-6}$ ). For this purpose we have used well known two tone and three tone methods that give an estimation of the intermodulation products arisen in the RF front-end. On the basis of the test results we recommend the modem to be used with the following QAM input signal levels: from 43 dB $\mu$ V to 73 dB $\mu$ V (for 64QAM) and from 47 dB $\mu$ V to 77 dB $\mu$ V (for 254QAM). The acceptable output signal levels for QPSK modulation are from 68 dB $\mu$ V to 118 dB $\mu$ V and for 16QAM – from 68 dB $\mu$ V to 115 dB $\mu$ V. If the mentioned above levels are smaller than recommended then BER is increased. On the other hand, greater signal levels result in an increasing of the adjacent channel interference and also in the passive distribution devices is originated intermodulation products owing to nonlinearity of the ferrites that it comprises.

## 7. REFERENCES

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