BROADCAST SIGNAL PROCESSING IN THE HEADEND OF A CABLE MULTIMEDIA SYSTEM

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Abstract

This article presents a block for processing of satellite and terrestrial television signals, received at the headend of hybrid fiber/coaxial (HFC) multimedia system. The architecture of the developed block and criteria for selection of its constituent modules (such as signal processors, digital receivers, remultiplexers, scramblers, DVB modulators, up-converters, etc.) are given. Appropriate schemes to implement some of the basic modules, building the block for broadcast signal processing, are suggested.

1. Introduction

The headend of a cable multimedia system is designed to receive the signals from satellite and terrestrial radio and television programs, to make processing of these signals for transmission to a cable distribution network and maintenance of an interactive communication with the users of additional services (Internet access, VoD, VoIP etc.). Processing of the received signals is necessary because of the different standards which are used in terrestrial (DVB-T/T2), satellite (DVB-S/S2) and cable (DVB-C/C2) broadcasting. Moreover, there are two systems for delivery of high-speed interactive services across cable networks (DOCSIS and DVB), which are incompatible. Therefore, there is a need to develop devices that can handle both standards. The application of such programmable and flexible devices in the headend and Set-Top-Box (STB) allows implementation of multiple standards on the same hardware platform [1-3].

Modern cable multimedia networks are always two-way, use optical fiber extensively, and are segmentable so as to allow simultaneous frequency reuse in various network sections. Two-way transmission of high-speed interactive services is performed by Cable Modem Terminal System (CMTS) that is located in the headend or in the hubs. Cable modem (CM) or STB is used in order to receive the date packets addressed to the subscriber and to transmit the date to the CMTS.

One of the main trends in the development of cable multimedia systems is to push as much as possible signal-processing equipment out to the hubs. This reduces the bandwidth requirement between headend and hub. For instance, if the VoD movies are stored at hubs and streamed from there to specific customers on demand, only the occasional content updates need be sent down from the headend to hub-based servers. Similarly, telephone host digital terminals (HDTs) at hubs can terminate calls from subscribers, and only the multiplexed DSx signals are transported over baseband optical links back to the headend where the switch is located. Such a solution allows furthermore reducing the possibility of outages affecting many subscribers simultaneously, and improving the quality of service [4-5].

The headend of a cable multimedia system can be divided into three fundamental modules. The first one is intended for processing of received broadcast signals, the second – for supporting interactive communication, and the third module provides network, services and subscribers management. The object of this paper is the architecture of the first module and the equipment needed for its building.

2. Modulation and Access Techniques for Down- and Upstream Channels

The systems here considered differ by using radio frequency (RF) carriers to transmit the information signals. Two frequency bands are provided for signal transmission from the headend to the subscribers: 112 MHz to 550 MHz (for analog video broadcasting) and 550 MHz to 862 MHz (for narrow casting services – data, voice and digital video). Analog video signals are transmitted by using VSB-AM while QAM methods (usually 256-QAM) are mainly used to transmit digital video programs and data. The system reverse paths make use of the 5 MHz to 65 MHz frequency band and subscribers' signals are transmitted by using QPSK or 16-QAM methods.

For transmission of RF signals over the optic fiber are used optic carriers whose wavelength may be 1310 nm or 1550 nm while with DWDM the wavelengths can be chosen from the wave range recommended by ITU. The transmission can be based on either direct laser modulation or an external modulator. The parameters of the optical channels with direct laser modulation are of poor quality due to laser chirping, nonlinearity and slightly sloping transfer characteristic etc. To eliminate such a disadvantage a laser with a constant bias current and an external modulator at its output is used.

The Frequency Division Multiplexing (FDM) technique is the traditionally employed access method in CATV broadcasting networks. This technique, however, has limitations if it were to be used for the support of the new multi-rate, multi-service, multimedia services. Most appropriate for these cases is the combined FDMA/TDMA method in which the upstream bandwidth is divided to a few dozens of FDMA channels, each shared by a limited number of subscribers on a TDMA basis. Each subscriber will be assigned to a particular carrier and his traffic cells will be multiplexed into particular time slots in this carrier.

3. Block for broadcast signal processing

On Fig. 1 is shown the architecture of a module for processing of signals, received by the satellite or terrestrial antennas and those that are obtained from local sources, such as cameras, VCRs and DVDs. As is known, in satellite transmission are used predominantly QPSK signals, while in terrestrial television is still large share of analog TV programs that are transmitted via VSB-AM signals.

In order to transmit received AM-VSB signals over the cable distribution network they should be moved to another channel, which differs from broadcast channel. For this purpose analog signal processors (ASP) are used. The digital signal processors (DSP) convert the signals of digital television programs from RF to baseband MPEG Transport stream (TS). The same functions perform the satellite receivers which are often associated with decoders to descramble the satellite signals. Such descrambling digital satellite receivers are often termed as integrated receiver-decoder (IRD).

Cable operators often create their own local movie, sports or news channels. Since the output audio/video signals from the cameras or VCRs and DVDs are analog, these signals need to be converted into a digital. Conversion of the analog A/V signals to a MPEG TS is done by the MPEG encoder. The encoders are relatively expensive devices and can account for a large share of the total headend cost.

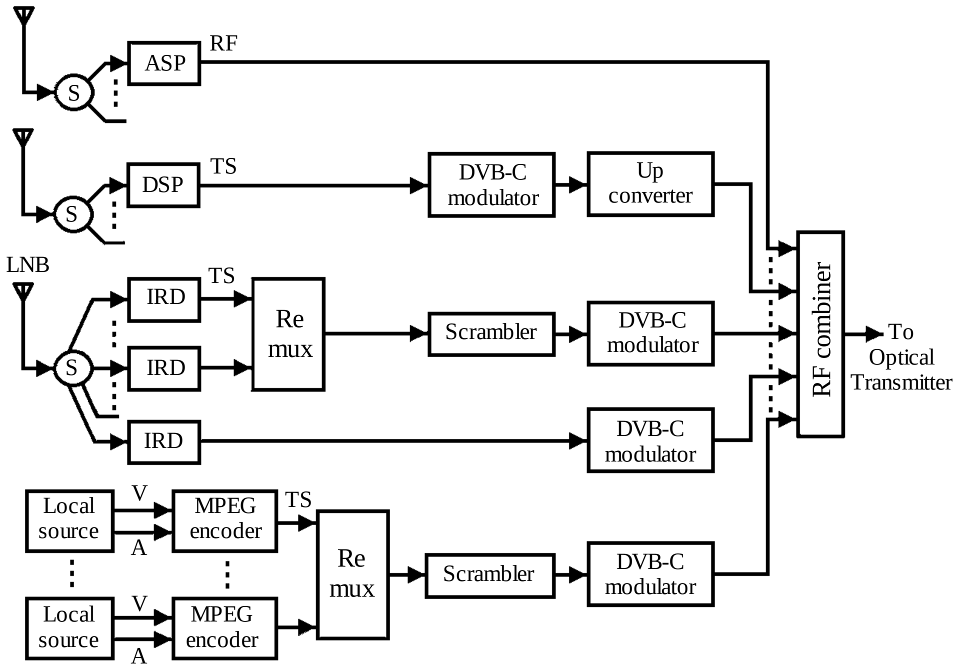

Fig. 1. Block for broadcast signal processing

The remultiplexers are used to form new transport streams that carry selected TV programs. Every remultiplexer has typically 8 or 16 ASI inputs, each of which is connected to its digital satellite receiver or MPEG encoder. It is very important to remultiplex the correct digital channels in each Transport stream. As is known, a news channel can be very efficiently compressed for transmission over a very small digital bandwidth. On the other hand a sports channel, which has a very high rate of a changing picture, cannot be compressed to the same extent as a news channel. Hence, efficient digital compression can be achieved if the remultiplexer creates its own re-bundle transport stream consisting of a mix of sports, news and movie channels.

Before submitting to the digital QAM modulators, the newly formed transport streams must be scrambled. This is done in order the signal to become unintelligible to those who are not authorized to receive it. After the QAM modulation the signal is fed to the upconverter which is frequency agile and the cable operator has the option of setting its output at any convenient frequency band in the cable TV spectrum. In many cases, the scrambler and upconverter are integral part of QAM modulators. Finally, the QAM signals are combined using conventional splitters. The output of RF combiner is the total set of broadcast signals, which are supplied to all subscribers.

4. Equipments required for developed block

This section deals with the electronic devices most commonly used in the headends to format broadcast signals for transmission on the cable plant. These devices include analog and digital signal processors, DVB-C modulators and up-convertors.

4.1. Signal processors

Signal processors are normally used to transfer incoming RF signals from off-air antennas or incoming cables to the cable plant.

Figure 2 illustrates a tipical block diagram of analog signal processor. The incoming VSB-AM signal is supplied to a bandpass filter, BPF1, which is tuned to the incoming channel. In mixer M1, driven by local oscillator LO1, the received RF signal is down-converted to the intermediate frequency (IF or f_i), where $f_i = 38.9$ MHz – for the picture carrier and $f_i = 33.4$ MHz – for the sound carrier. The IF signal is up-converted to the assigned output RF channel in mixer M2, driven by local oscillator LO2. Band-pass filter BPF3 eliminates the image of the second conversion process and any spurious signals coming from mixer M2.

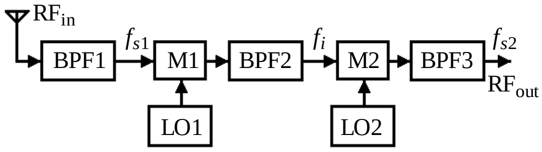

Fig. 2. Analog signal processor

On Fig. 3 a simplified diagram of the digital signal processor is shown. A digital signal is recovered off-air in DVB-tuner 1 and supplied to the PSIP processor and remultiplexer (remux). Processing of the received signal in the tuner includes: demodulation, analogue-to-digital conversion, filtering, error-protection decoding, removing the randomizing pattern. As a result, the MPEG transport stream (MPEG-TS) is obtained.

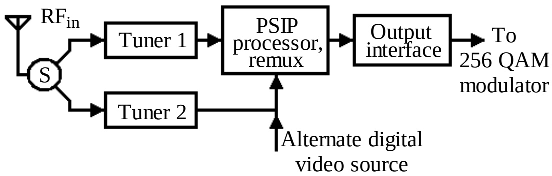

Fig. 3. Digital signal processor

As is known, digital video signals include the program and system information protocol (PSIP), a series of tables that tell the receiver what programs are included in the multiplex and how to find them. These tables must be modified if some programs are removed from the multiplex and others are added from another off-air channel or other source.

In the configuration shown, a second program stream may be added from either another off-air channel via DVB-tuner 2 or from another signal source. This program transport stream is supplied to the PSIP processor and remux. Its PSIP tables are merged with those from the first program stream and multiplexed into a higher-bandwidth stream that is supplied to a 256-QAM modulator.

4.2. DVB-C modulator

Figure 4 shows a tipical block diagram of DVB-C modulator. The modulator locks to the MPEG transport stream fet to it at the baseband interface and consisting of 188 byte-long packets. In order to ensure adequate binary transition, a randomization process has to be applied to the MPEG-TS. To produce an error-protected packet a shortened Reed-Solomon (RS) code is applied (Type 204,188) with the ability to correct eight random byte errors. The packets, which are then 204 bytes long, are supplied to the convolution interleaver to make the data stream more resistant to error bursts. It is based on the Forney convolutional approach with I = 12.

The error-protected data stream is then fed into the mapper where the QAM quadrant must be differentially coded, in contrast to DVB-S and DVB-T. Then the signal is roll-off filtered with a roll-off factor of α = 0.15 and supplied to the QAM modulator.

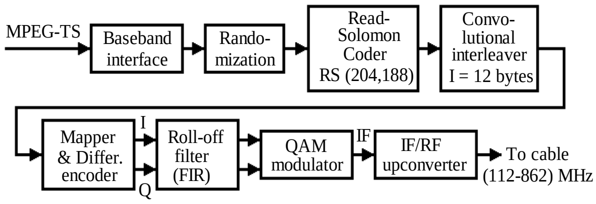

Fig. 4. DVB-C modulator

Since the modulation is performed on IF, the signal must be up-converted to the output channel. In some cases, the modulator includes the up-converter to the final channel assignment, in other cases, the up-converter will be external to the modulator.

One issue of concern is when scrambling is added in a digital transmission stream. In some headend systems, there is an external scrambler that adds scrambling prior to the modulator. In other headend systems, the scrambling is an integral part of the modulator.

4.3. Up-converter

If the output of the signal processor is frequency agile, meaning it can be set to any of a number of channels, the up-convertor is replaced with a dual conversion output section, with a first IF above the maximum frequency the processor can output. Then the signal is filtered to remove the image, and down-converted to the output channel (Fig. 5).

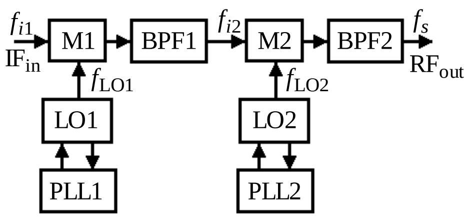

Fig. 5. Dual-conversion up-converter

The first local oscillator will up-convert the incoming IF signal (f_{i1} = 38.9 MHz) to some high frequency f_{i2} (f_{i2} must be higher than 862 MHz), i.e. the first local oscillator, LO1, operates at frequency f_{LO1} = = $f_{i1} + f_{i2}$ = 38.9 + f_{i2} MHz. There may be some amplification at this second IF frequency before the signal is converted to the final output frequency in mixer M2, driven by local oscillator LO2. If the frequency for selected channel is f_s (f_s = 112 ... 862 MHz) the frequency of LO2 will be $f_{LO2} = f_{i2} + f_s$.

The presented agile up-converter provides low spurious outputs. It is easy to establish that the image of both the first and the second conversion is well above any frequency we are interested in on the cable plant, and so far from the output frequency that it is easy to filter. This type of convertors are best for setting the output of modulator (analog or digital) or CMTS on any frequency.

5. Conclusion

The block for broadcast signal processing presented in this paper ensures transmitting of both terrestrial and satellite radio and television signals through cable distribution networks. With its designning, the requirements of existing DVB standards are taken into account. The block was tested in order to determine the acceptable signal levels that ensure given parameters at the headend output.

6. Appendix and acknowledgments

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