A DIGITAL VIDEO COMPRESSION SYSTEM FOR SATELLITE VIDEO DELIVERY

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Abstract

Compression Labs has developed a complete digital video/audio compression system for transmitting multiple NTSC video signals over a single satellite transponder. The system is operational and equipment production has begun. Using VLSI technology, very low-cost downlink equipment was developed for placement in consumer premises. Although the initial application was for direct broadcast satellite, the technology has application in many video media delivery systems, including cable and over-the-air.

System Description

The Compression Labs satellite communications system is composed of transmitter and receiver subsystems (Figure 1). The heart of the transmitter is the encoder, which compresses a video input to 1.8 Mbps, multiplexes this video with two channels of digital Dolby™ adaptive delta modulation (ADM) audio and a data channel, and outputs this multiplexed bit stream to a satellite QPSK modulator. The Dolby™ audio is coded at 200 Kbps per channel, for a total of 400 Kbps. A data channel of at least 19 Kbps can be sent along with the compressed video and audio. Video and/or audio bits may be replaced with data to yield data rates up to 2.2 Mbps. With forward error correction, total data rate output to the QPSK modulator is 3.0 Mbps. The encoder is controlled by a microcomputer or terminal which issues commands via a serial interface or by entry of commands via a front panel keypad.

The QPSK modulator receives the 3 Mbps multiplexed video/audio/data bit stream and digitally modulates a carrier within a satellite transponder bandwidth to an IF range of 52-88 MHz. The IF signal is then upconverted to the desired satellite GHz band (Ku or C). Carrier selection within the transponder bandwidth is made under computer control or via the front panel switches of the modulator. Multiple channels may be transmitted in a single transponder, with the exact number depending upon link budget parameters such as antenna size, transponder power and others. The system is a single channel per carrier (SCPC) type. A time division multiplex of multiple video channels onto a single carrier at a higher modulation rate is also feasible. The SCPC technique was selected to minimize consumer downlink equipment cost.

The receiver uses conventional antennas and low noise block converters (LNB) to acquire a signal from a satellite, amplify it and downconvert it from GHz to 950-1450 MHz. The Integrated Receiver/Decoder (IRD) contains a satellite QPSK demodulator and a video/audio decoder (Figure 2). The QPSK demodulator selects a given channel within this 500 MHz. Channel selection is via front panel buttons, from an optional infrared remote, or upon command from the uplink via the satellite. Since each channel occupies approximately 2 MHz, 250 channels are simultaneously available. However, the demodulator synthesizer operates in 125 KHz steps, permitting 4000 possible channel frequencies. The output of the QPSK demodulator is a 3 Mbps multiplexed bitstream containing compressed video, compressed audio, data and control bits.

The video/audio decoder forward error corrects the bit stream output by the demodulator and demultiplexes the command, video, audio and data information. The video is decompressed, converted to baseband composite video and output to a monitor. An optional channel 3/4 RF modulator output is available. The compressed Dolby™ Adaptive Delta Modulation (ADM) audio is decoded, converted into analog stereo signals and output to an audio amplifier.

Data at rates of 19 Kbps-2.2 Mbps is available at an external connector. The system operator can define the meaning of the data as desired. For example the data transmission capability can be used to broadcast text, either in ASCII format or facsimile formats. External add-ons interpret the data stream appropriately. For example a facsimile machine could receive a data stream representing Group III encoded fax.

Information such as menus and system status can be displayed on the video screen. Conditional access and hardware encryption are also available. VCR control signal outputs are available to control video recording at the decoder remotely from the transmission source.

Figure 1. Compressed Digital Video Satellite System Block Diagram

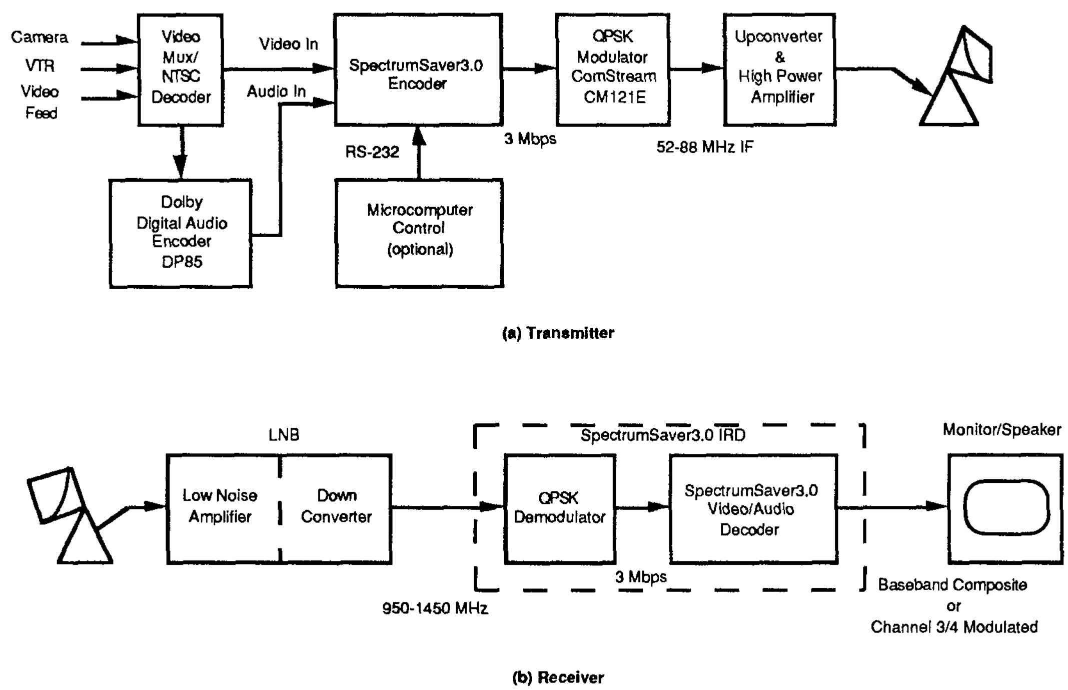
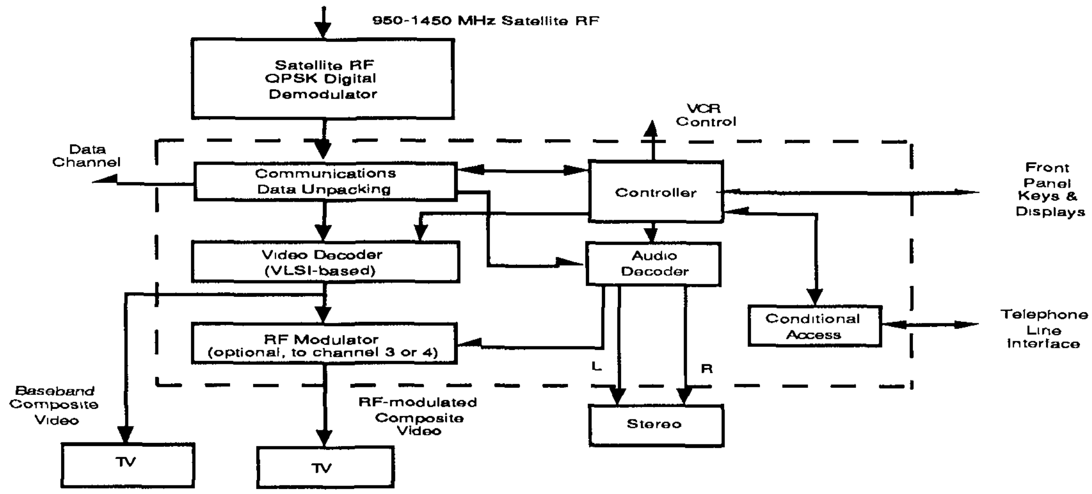


Figure 2. Compressed Digital Video Satellite Integrated Receiver/Decoder Block Diagram



System Design

From its 15 years experience coding many different types of video sequences, CLI made appropriate tradeoffs to optimize this satellite delivery system for its major objectives of:

- 8-16 channels per transponder
- "Better-than-VCR" quality (consumer tested)
- Affordable consumer price for customer premise equipment ($150-$300)

The "better-than-VCR quality" was determined using consumer focus groups viewing simulations at various bit rates. The quality judged acceptable by consumers over a wide range of video sources was realizable at a compressed bit rate of 1.8 Mbps for the video. The system is actually capable of operating at higher and lower compressed bit rates as well. An important quality advantage of digital video is the lack of transmission artifacts such as random noise, ghosting, etc.

Video Compression

The video compression algorithms are derived from proprietary CLI algorithms. They are based on the discrete cosine transform (DCT), variable-length coding, conditional replenishment and motion compensation. The various algorithm parameters were tuned to the requirement of "better-than-VCR quality" for satellite delivery:

- Spatial resolution of 480 lines with 368 pixels per line
- Full color
- Full 30 frames/second motion rendition
- Compression ratio of over 50:1

CLI selected DCT technology because:

- This technology can meet the requirements of the application (quality, bit rate, cost)
- The technology is aligned with international compression standards (Px64, JPEG, MPEG)
- The company has extensive experience with the technology

Key to the excellent performance of the algorithms is the extensive use of powerful custom VLSI to implement comprehensive motion estimation and compensation, as well as special adaptive pre- and post-processing to make appropriate tradeoffs matched to the visual system.

In the consumer IRD, video decoding is performed by three VLSI chips. Two of these are custom and one (a DCT chip) is off-the-shelf. Coupled with half a megabyte of video memory, these VLSI chips implement a low-cost solution suitable for sale to consumers.

Audio Compression

Dolby™ ADM audio compression was chosen because it has good quality, a reasonable compressed bit rate and very low cost. Two channels of compressed audio are provided. Each is compressed to 200 Kbps, for a total of 400 Kbps of compressed audio. At the time of system design decisions, this was the only solution available for less than $10. in the decoder. It is based on a single chip decoder supplied by Philips/Signetics, with the algorithm licensed from Dolby.

Digital Transmission

The RF QPSK modulation technology is based on well-known VSAT data transmission technology. An SCPC technique was selected over TDM because a 3 Mbps demodulator is less expensive than a 30 Mbps demodulator, allowing for the lowest cost of the consumer IRD equipment. A key objective of the system design was to allow use of very small receiver antennas, less than 1 meter. These are low cost and easy to install. To this end, the modem design has an E_b/N_o of 7 dB. Coupled with a proprietary forward error correction technology implemented in a custom chip in the IRD, this modem technology allows transmission of about 10 channels on a medium power satellite such as Hughes SBS-6, with less than a 1 meter receiver antenna.

Bandwidth limitations allow nearly 20 channels to be transmitted. However on medium power satellites the system is power limited. With the launch of high power satellites in future years, the system can be expanded to many more channels, without changing the existing IRD design. More channels can be sent with existing medium power satellites if larger receiver antennas are used.

Conditional Access

The system contains highly-secure conditional access mechanism. Each IRD has a unique address.and encryption key information. A telephone line interface is included to allow for feedback from each box and/or to update key information in the IRD. Key card update of keys is also feasible.

In addition, the complexity and proprietary nature of the compression technology, including the custom VLSI, makes it extremely difficult to reverse engineer the IRD.

Application of Technology to Cable

The technology used in this direct broadcast satellite system can also be applied in cable systems. Two applications are:

- Delivery of digitally compressed program video from programmers to cable headends via satellite
- Delivery of digitally compressed video directly from the headend to consumer homes over the cable

The video and audio compression can be very similar for cable. Delivery to headends for analog transmission to homes may use studio quality video compression to account for signal degradation down the analog cable. This requires higher bit rates. Approximately 4-6 studio quality video channels can be sent over satellites, thereby reducing transponder costs.

The major difference for compressed digital video delivery directly from the headend to the consumer is in the digital transmission technology. A different RF modem from that used in the satellite system is required.