Digital Television and the PC

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INTRODUCTION

The dawn of Digital Television is an inflection point in what has sometimes been referred to as "convergence" technology – the blending of various features of computing, communications and broadcasting. As with any other technological watershed, there will be changes, risks and opportunities in this transition period. This paper is an attempt to bring together, in one place, descriptions and explanations of those aspects of Digital Television that are relevant to people involved in the Personal Computer industry.

WHAT IS DIGITAL TELEVISION?

A Digital Television (DTV) signal is transmitted over the same general set of frequencies used by analog television broadcasts, but instead of continuous analog components carrying video and audio information, there is a single, high-speed bit stream. This bit stream is a combination of encoded video, encoded audio and system data.

Digital Video vs. Analog Video

The analog television video standard in the United States is NTSC composite video. It is called "composite" because it is the combination of base-band luminance information up to about 3 MHz, a separate signal which encodes chrominance modulated onto a 3.58 MHz subcarrier, and horizontal and vertical synchronization signals represented as negative-going pulses.

In contrast, a digital video signal is created by digitizing the image to be transmitted into a frame of pixels, then reducing the number of bits needed to represent the image using a compression method sanctioned by the Motion Picture Experts Group known as MPEG-2. MPEG-2 uses techniques such as Discrete Cosine Transformation (DCT), motion estimation, and predicted frames in order to accomplish this compression.

Digital Audio vs. Analog Audio

The analog audio that accompanies analog video is simply modulated up onto a 4.5 MHz subcarrier prior to inclusion in the broadcast envelope. Should stereo audio be desired, the presence of a pilot tone signals the receiver that the base-band audio information consists of the sum of the right and left channels, and that a difference signal is available at a slightly higher frequency in the broadcast envelope. A Secondary Audio Program (SAP) may also be present at yet another frequency. This method, sanctioned by the Broadcast Technical Systems Committee, is similar to that used in FM stereo radio transmissions with the exception that a frequency-dependent companding method known as dbx-TV, licensed by THAT Corporation, is used to reduce the effects of system noise. If surround sound matrix information such as Dolby Surround Pro Logic is included in the original source material, it is preserved by this transmission method, allowing a receiver to reproduce the center and surround channels if desired.

On the other hand, a digital audio signal is created by digitizing the sound to be transmitted, then compressing the number of bits needed to represent the audio signal using a compression method called AC-3 (also known as Dolby Digital), which provides for 5 separate channels of audio plus a low-frequency subwoofer channel.

Established Digital Approaches

Consumers are already familiar with several digital technologies in the entertainment area – Direct Broadcast Satellite (DBS), Digital Versatile Disc (DVD) and Compact Disc (CD). Both DBS and DVD technologies use MPEG-2 encoding to dramatically reduce the bit rate required for transmission of video content, and all three use digital audio. They also permit the addition of data, typically a program guide in the case of DBS, extra program-related content for DVD, and song titles and artist information on CD. The fact that these technologies actually deliver on the promise of high-quality pictures and sound should help position DTV in the minds of consumers.

The ATSC Formats

The Advanced Television Systems Committee (ATSC) has established 18 approved formats for the broadcasting of DTV in the United States. These formats are encoded into a stream of binary bits, which are then modulated using a method known as 8VSB into a 6MHz analog channel "envelope" in preparation for transmission. The broadcaster then "up-converts" the signal to the frequency that has been allocated by the Federal Communications Commission (FCC), and it is sent to the transmission tower. Manufacturers of receivers are encouraged to support all of the formats in order to increase consumer satisfaction and reduce confusion in the marketplace.

It is important to note that a digital broadcast is simply an encoded stream of binary information at a rate of 19.4 Million bits per second. The broadcaster and receiver are responsible for imposing meaning on this bit stream. In fact, it is often useful to think of a DTV transmitter and the receivers tuned to it as being a kind of high-speed unidirectional data network. Since the number of bits per second actually used by the encoded video and audio will vary widely depending of the chosen format and efficiency of the encoding process, there will typically be a portion of the bit stream remaining unused. These "extra bits" can be used to transmit additional data along with the primary program content being broadcast.

There has been considerable debate in the market regarding which of the 18 formats should be used, by whom, and for what purposes. For instance, an initiative by Intel, Compaq and Microsoft in early 1997 to establish a set of medium-resolution progressive-scan formats as a "first step" to market acceptance of digital broadcasts met with negative responses from consumer equipment manufacturers. The CE community saw this as an attempt by the PC industry to gain control of the new broadcast medium, and did not want to be tied in any way to the standards of the PC market.

Digital Television (DTV)

The acronym DTV is normally used to encompass all digital television broadcasts and formats, including High Definition Television (HDTV), Standard Definition Television (SDTV) and the use of digital signaling to broadcast data.

HDTV

It is generally held that the term HDTV refers to any of the six broadcast formats that provide greater detail than the approximately 640x480 pixels in a good quality NTSC television picture. There are two groups of such formats: 1,920x1,080 pixels refreshed 60 times per second at a 2:1 interlace (yielding 30 complete frames per second), or refreshed progressively at either 30 or 24 frames per second; and 1,280x720 pixels refreshed progressively at 60, 30 or 24 frames per second. All of the HDTV formats use a 16:9 "widescreen" aspect ratio. The formats using 24 frames per second are designed to allow excellent reproduction of motion picture (movie studio) content, which would otherwise suffer timing artifacts from being converted to 30 or 60 frames per second.

SDTV

The ATSC approved a total of 12 formats that are collectively referred to as Standard Definition Television. This was done in order to accommodate the wide variety of source material, and to enable easy conversion from a number of existing formats, and from the PC world, to digital broadcasting. The 12 SDTV formats are the result of all possible combinations of three resolutions with four frame rates. The resolutions are 704x480 with pixels compressed slightly yielding a 4:3 aspect ratio, 704x480 with pixels expanded slightly to yield a 16:9 aspect ratio and 640x480 with square pixels for an exact 4:3 aspect ratio. The frames are refreshed 60 times per second at a 2:1 interlace (yielding 30 complete frames per second), or refreshed progressively at 60, 30 or 24 frames per second.

Multiplexing / Multicasting

Only the highest resolution formats require the majority of the 19.4 Megabits per second that make up a DTV broadcast. In fact, depending on the encoding used, a Standard Definition program can be made to use as few as 4.5 Megabits per second, sometimes even less. This opens new opportunities for broadcasters, who can take advantage of this situation by transmitting more than one program within a single 19.4 Megabit stream, and/or adding various kinds of data to the stream. Some uses for this technique include multiplexing several unrelated programs (typically 4) on a single feed, multicasting a single program such as a sporting event from several different camera angles (allowing the viewer to select the point of view by changing to a different program within the stream) and broadcasting multiple time-shifted copies of a program.

Another interesting proposal has been to allow for some limited forms of interactivity by letting a viewer select a different ending to a movie, or select an answer to a question during a distance learning program with the choice resulting in positive feedback or a further explanation of the topic. Finally, in a PC environment, either the “extra bits”, or even the entire 19.4 Megabit stream, can be used for the broadcast of data. By way of comparison, a 19.4 Megabit stream could transfer the contents of an entire CD-ROM in just five minutes!

The FCC’s DTV Implementation Plan

The Federal Communications Commission, a part of the government of the United States involved in making sure that communications technologies best serve its citizens, has a multi-step plan for the implementation of Digital Television that attempts to take into account the realities of the consumer broadcast markets. In order to encourage broadcasters to deploy Digital Television, the FCC allocated an additional broadcast channel for each broadcaster currently transmitting using analog television technology. With some broadcasts beginning this fall, digital broadcasts are required to be available to half of all U.S. households by a year from now, and to all by May of 2002.

While there is apparently no legal requirement for a broadcaster to use the new frequency allocation for HDTV (as opposed to SDTV, Multiplex, Multicast or even pure data) transmissions, there is strong political pressure in Congress for such use, at least for part of the broadcast day. It is also the intent of the FCC and Congress that DTV transmissions be “free” to receivers, inasmuch as there has been talk of inventing new taxes on broadcasters who profit by the transmission of access-controlled programming.

Often characterized as a “give-away”, the additional frequency is actually “on loan” to the broadcaster to allow the start of digital broadcasting in parallel with the existing analog system. Beginning in the year 2006 the FCC plans to begin taking back the then-obsolete analog frequencies and auctioning them to the highest bidder. By then, it is reasoned, the maturing demand for digital services will drive a larger premium for those frequencies than could have been obtained today. At the same time, the cost of set-top conversion boxes for consumers unable or unwilling to buy new digital televisions will have fallen to easily affordable levels, allowing service for all and disenfranchising none.

THE IMPORTANCE OF DTV TO THE PC INDUSTRY

The inception of DTV will create new opportunities for the PC industry. These opportunities revolve around three general ideas – PC’s used as DTV receivers, DTV reception in PC’s, and Data Broadcasting.

Opportunities for PC OEMs in the TV Market

For several years, various PC manufacturers have offered PC's with large-screen displays for use as "theater"-type televisions. While moderately successful, the product category has been hampered by being more expensive than its main competitor, the large-screen television set. Most of the prospective customers with the disposable income to purchase a high-end PC with a large-screen display already have a large-screen television, and are probably fairly happy with it. The battle to unseat an incumbent is a difficult one!

However, there are no large numbers of Digital Televisions in America's living rooms today. As consumers consider the purchase of an HDTV, they could also be shown the capabilities and benefits of a high-end PC with a large-screen display, equipped for DTV reception. Such a unit is likely to cost far less than an HDTV, and offer increased benefits, such as Internet access. PC manufacturers do not need to capture a large percentage of potential HDTV purchases in order to significantly increase their unit sales and revenues.

The PC-in-a-TV Market

The market for analog television receiver cards for installation in PC's has increased by 50-100% in each of the last three years. Users install television receivers in PC's primarily for the entertainment value, for instance, to be able to watch television while surfing the Internet. There are also business and educational uses for these cards. Pre-installing a DTV receiver in some models of its product line might make a PC manufacturer's products more attractive to end-users.

Economics of PCs vs. TVs

Most consumer HDTV sets are being introduced at price points between $5,000 and $10,000. A well-equipped PC, with a DTV receiver and a large-screen monitor, should cost the consumer no more than half as much, and offer far more functionality.

Connectivity and the Future of Data Broadcasting

Connectivity is very important to PC users, many of who purchase a PC with the express purpose of being able to access the Internet or other communications resources. With the advent of DTV broadcasting, the potential exists for digital broadcasting to play a role as a high-speed, unidirectional "overlay" to the Internet. Over time, data that is accessed by many people can be broadcast, leaving the traditional bi-directional Internet more available for true point-to-point communications, such as e-commerce and video teleconferencing. There are various business models available for the Data Broadcast market to exploit, including advertiser-supported and pay-for-information possibilities.

Microsoft's PC99 Standard

Each year, Microsoft publishes specifications for baseline PC configurations optimized for targeted markets. These specifications are a guide to PC manufacturers, setting minimum expectations for these systems, which will in turn be used by software developers to identify features and performance characteristics that can be counted on. The goal is to create a better, more supportable experience for the PC user. PC99 encourages PC manufacturers to include both analog and Digital Television receivers in certain PC categories.

CURRENT ISSUES IN DIGITAL BROADCASTING

DTV and the Cable Industry: VSB vs. QAM

One of the thorniest current issues in DTV is the role of cable MSO's. On the one hand, the "must carry" rules might be interpreted to mean that cable operators must find a clear frequency on their cable for each broadcaster in their region with a digital signal and simply carry the same signal that exists over the air on their cable system. But many cable operators have fairly full systems, with very few if any available channel allocations. This means that one profitable cable network would need to be sacrificed in order to make room for each new digital broadcast.

To further complicate matters, many cable operators are in a digital rollout of their own, with new digital set-top boxes that provide more features and capabilities at lower costs. By and large, cable systems use a digital scheme known as Quadrature Amplitude Modulation (QAM). Among the new features are better access control, and the ability to carry up to 9 properly encoded programs in a single 6Mz channel. Some cable MSO's ask why they cannot simply "carry" the existing channels by multiplexing them onto a single channel, and transcoding the VSB broadcasts into QAM. While perhaps in violation of the spirit of the "must carry" rules, because all subscribers would now need a digital set-top box, this method probably preserves the most television channels for the most people. As of this writing, this issue is far from being settled.

DTV over Satellite

While the earliest satellite television systems were analog and required large dish antennas, the current generation of DBS products use digital signals and smaller dishes to implement resolutions comparable to SDTV. Nothing is stopping the satellite operators from transmitting HDTV, except for the lack of consumer HDTV sets. Satellite transmissions have tended to use Quadrature Phase Shift Keying (QPSK) modulation, so it is also not clear what method would be used to connect a satellite HDTV receiver to a consumer HDTV set. Among the leading possibilities are IEEE 1394, or transcoding from QPSK to VSB modulation.

Cable Modems and DOCSIS

Cable modems provide for very fast downstream delivery of data and a relatively slow return path. In fact, some cable modems use a regular dial-up telephone line as a return path. Because cable modems can coexist on a broadband cable system along with analog and digital televisions, strict specifications are needed to ensure that these devices do not affect each other. Cable Laboratories has developed the Data Over Cable System Implementation Specification (DOCSIS) in order to address these issues, and to standardize interoperability among the various manufacturers of cable modems. Cable modems typically use a QAM modulation scheme.

Future Technology "Merge" Strategies

While the implementations are different, most of the "Broadband Digital" technologies discussed share a number of common elements. These include the need for tuning to select the desired channel from the broad band, the need for demodulation to extract the binary bit stream, and - for the Digital Television technologies - the need for decoding to render the video and audio into a form the viewer can appreciate. While these technologies are each currently complex enough to require unique solutions in terms of modules, integrated circuits, and software, as VLSI technology continues its relentless advance we can look forward to the day when several might be combined in one product.

The development and deployment of these combinations will be driven as much by market demand as by technical progress. For instance, the desire on the part of consumers for a simple functional concept might motivate the combination of Broadcast and Cable Digital Television, creating a single product that can receive broadcasts via either transmission method. The desire for simple installation and cabling might drive the merging of Digital Television receiver and Cable Modem functions.

Access Control Issues

MPAA Concerns

The Motion Picture Association of America (MPAA) represents movie producers, and is concerned about the possibility of perfect digital copies being made without authorization. In order to minimize this possibility, the MPAA is insisting that encrypted protocols be used whenever the DTV signal is transferred from one component to another, for instance, from a DTV “set-top” receiver to the high-resolution display.

The Role of IEEE 1394

One method that has been proposed to satisfy the MPAA requirement is to use a high-speed digital link such as the IEEE 1394 bus to communicate between the receiver and display. New encryption keys would constantly be exchanged between the two, making a simple recording of the externally visible bits useless. Some camcorders and VCR’s already have 1394 interfaces, as do a few PC’s, so the industry has a growing knowledge of this technology.

IMPLEMENTATION DIRECTIONS

The roll-out of Digital Television promises to be one of the more confusing in recent memory, as consumers are faced with a number of complex choices, and relatively little information on which to base buying decisions. In the words of Joseph Flaherty of CBS, “if they’re confused, they’ll just put their money right back into their pockets.”

There will be a number of ways for consumers to receive Digital Television broadcasts, each with its own set of trade-offs. We expect the most common implementations to be:

Initial Consumer HDTV Sets

Initial consumer HDTV receivers are just now making their way into appliance stores. They are typically implemented as two pieces – a high-resolution 16:9 display and a “set-top” receiver. In some cases, manufacturers have been talking about replacing the receivers to handle any changes that turn out to be needed to accommodate the movie industry’s concerns about access control. Given the size and weight of the monitors, this makes a lot of sense!

Capabilities and Performance

While it is clearly in the best interest of all concerned that no appliance sold as a HDTV receiver should “go black” for any broadcast format that it is tuned to, the actual display resolution of the first wave of consumer HDTVs is expected to vary widely. According to some reports, many of the large-screen displays that will be shipped will only have about 600-800 lines of horizontal resolution, a far cry from the 960 that a 1,920-pixel format would imply. The manufacturers apparently intend to down-sample the image in order to display the highest-resolution broadcasts on these displays. While viewers will still be very impressed with the picture quality, there will no doubt be plenty of opportunities for the magazine reviewers and test laboratories to do their jobs, comparing the offerings of the various manufacturers, just as they do with today’s prevailing analog products.

Early Set-top Box Products

The purpose of a set-top box is to adapt a particular broadcast technology to a different receiving technology. For instance, most cable television subscribers are familiar with the need for a set-top box to handle access control for premium and pay-per-view channels. In the case of Digital Television, the purpose of the set-top box will be to receive the DTV broadcast, convert it to a standard definition signal, and pass it on to an analog television for display. The three available ways to implement the path from set-top to television are, in decreasing order of performance, S-Video, Composite Video, and RF (the familiar “Channel 3 or 4” technique).

Capabilities and Performance

Again, as with full-fledged HDTV receivers, set-tops will generally receive all broadcast formats. However, unlike HDTV receivers which must be touted as having great resolution in order to justify their price tags, set-tops can be expected to be sold primarily on price, as a way for the consumer to receive DTV broadcasts without needing to buy a new television. As such, they are likely to have just enough resolution to get by.

In the case of a set-top that outputs S-Video, resolution will be on the order of 300-400 horizontal lines in the Luma signal (roughly 600-800 pixels), with some softening of color edges due to the reduced bandwidth of the Chroma signal. To the viewer, this will approximate the quality of a Digital Satellite broadcast. When connected via a Composite video path, the resolution will be degraded by two factors – the reduction in luminance bandwidth to accommodate the chrominance signal, and the re-introduction of "chroma crawl" due to the tendency of analog television sets to interpret detail in the luma signal as chroma information and vice versa. The need to connect to some older televisions via RF will result in all of the problems of a Composite connection, plus the inherent addition of noise (snow) to the signal due to the modulation and demodulation steps.

PC + Customized Set-top Box

Some PC's are already equipped with the ability to receive analog television broadcasts, many more are able to capture Composite and/or S-Video signals and display them on the PC's monitor. Simply adding a set-top box as described above will allow for the reception of DTV broadcasts. If the set-top box is specifically designed for use with such a PC, additional capabilities can be added.

System Requirements

A PC equipped for use with such a set-top will have an S-Video input, a provision for control of the set-top (such as an I^2C or USB connection), and an external input for the broadcast's audio component. If the PC already has a television tuner, it will now be capable of receiving both analog and digital transmissions.

Product Capabilities

A customized set-top box should be able to receive broadcasts in any DTV format, render the video portion of the program into S-Video and the audio portion into a stereo, line-level signal. To the viewer, this will approximate the quality of a Digital Satellite broadcast in terms of both picture and audio quality. In addition, a connection could be provided for transferring to the PC any data that may be part of the broadcast.

PC + PCI Card

One of the most obvious ways to add Digital Television to a PC will be through the use of a PCI-based add-in card. With analog television receiver cards becoming increasingly popular, their digital counterparts are not far away. There will be two main implementation directions:

Software-based Alternative

As mentioned above, one way to analyze a digital broadcast is simply as a 19.4 Megabit network feed. The DTV program is then one of what may be any number of simultaneous streams of data, a bit stream which must be rendered into pictures and sound in order to be appreciated by the viewer. The requirements of this rendering are then similar to, but more demanding than, those imposed by a desire to watch streaming video over the Internet.

System Requirements:

The hardware requirements consist of a tuner to select the desired channel out of the frequency bands available, a demodulator to extract the 19.4 Megabit binary stream, and an interface to a standard PC bus. The PCI bus is the logical choice here, partly because the 19.4 Megabit stream is equivalent to 2.43 Megabytes per second, which is too large a fraction of the bandwidth of the ISA bus to be practical, but also because the ISA bus is an endangered species! A further requirement is a high-performance CPU, given the software stack that must be supported.

Once the bit stream makes its way across the PCI bus into the PC, several layers of software handle it. A device driver controls the PCI card itself, and arranges for the bit stream to be placed in buffers in memory. Higher layers of software filter the bit stream in order to synchronize and separate the video, audio and PSIP streams.

The video stream is decoded from MPEG-2 into a sequence of frames by a software decoder, which may receive a performance boost from specialized functionality built into the PC's graphics display subsystem. The audio stream is similarly handled en route to the PC's sound subsystem. The software responsible for the Human Interface uses information from the PSIP stream to allow the user to navigate between and, in the cases of Multiplexing or Multicasting within, channels.

Resolution / Performance Roadmap:

As might be expected, this software-oriented approach places great demands on the PC's CPU. In particular, the MPEG-2 decoding is very compute-intensive, especially if there is not a good deal of computational support built into the graphics display subsystem. Currently, SDTV formats can be handled by a Pentium-II / 450MHz class processor; HDTV formats must be down-sampled in order to be rendered by that class of machine. Of course, faster processors will be available in the future, making this type of implementation increasingly plausible for OEM PC manufacturers who control the characteristics of the machines that they build.

Hardware-based Decoding

Another approach is to use a hardware processor to decode the video and possibly the audio streams. While this adds cost, it dramatically reduces computational requirements, making after-market add-on DTV receivers a possibility.

System Requirements:

The hardware consists of a tuner to select the desired channel, a demodulator to extract the 19.4 Megabit binary stream, a hardware decoder to render the MPEG-2 video stream into a sequence of frames of pixels and a PCI bus interface. Typically, a board such as this will transfer the rendered pixels directly into the frame buffer of the graphics display using master-mode bus transactions so as not to burden the CPU. In order to host such a board, the PC will need to have a graphics display subsystem with solid DirectX drivers.

The software involved consists of low-level device drivers that set up the board, a software stack that interfaces with DirectX to arrange a display window in the graphics display subsystem, and Human Interface software for control and navigation.

Performance and Resolution Issues:

A hardware-based decoder could in principle render its input stream into any desired format. In most cases, the output format will be chosen so as to be compatible with other data types that the PC handles well. For instance, if a PC is already optimized to deal with NTSC images, the decoder could be set to render all ATSC input formats into an SDTV resolution, for forwarding to the graphics display subsystem in cooperation with DirectX.

As the resolution of the output format increases, two additional practical factors come into play. One of these is the bus bandwidth required to move the live video image across the PCI bus from the decoder to the graphics display subsystem, while the other relates to the performance of the graphics display subsystem itself. Transferring SDTV is not a large load for the PCI bus, but transferring 1,920x1,080 resolution HDTV images 30 times a second will almost completely fill up the bus. At the same time, the graphics display subsystem must be able to accept and display all of that information.

Yet another minor variant of this architecture would be to have the video decoding circuitry as close as possible to the graphics display subsystem. The advantage of this variant is to keep the traffic on the PCI bus low, since only the undecoded streams must travel across it. The disadvantage is cost, since the system always carries the cost of the decoder, even when the DTV board is not installed.

Mid-range Consumer Digital Televisions

While the initial motivation for most consumers purchasing DTV will be the enhanced quality available with HDTV programming, which is best experienced on a large screen, the widespread deployment of digital broadcasts will result in additional product categories. Chief among these is the mid-range consumer DTV, which will begin to replace the market niche currently served by 19-27" analog televisions. These units are not likely to sport full 1,920x1,080 pixel resolution, but will receive all DTV formats, rendering the HDTV programs into display resolutions somewhat better than SDTV, at costs comparable to today's mid-range televisions.

Consumer 1394 Boxes in the PC Market

As mentioned above, some consumer electronics companies are planning on using the IEEE 1394 interface as the "secure channel" between their receivers and displays. While not yet widely deployed in the PC world, IEEE 1394 interfaces are available and growing in popularity. It is likely that in the future, a consumer DTV receiver that outputs 1394 can be connected to a PC with the appropriate software, creating another alternative for DTV reception and display.

Device Bay and Digital Television

The need to open a PC to add a device such as a DTV receiver card creates a confrontation level that many PC users cannot overcome – they will simply make do without the enhanced capability. The Device Bay standard fills the need for a way to expand the capabilities of a PC without opening the chassis. Device Bay consists of an IEEE 1394 channel, a USB port, and a standardized physical form factor that allows the unsophisticated user to easily attach a high-performance peripheral device. Although it is not yet included on mainstream PC's, once Device Bay becomes more widely available it will be another good alternative for adding DTV capability to a PC.

GLOSSARY OF DTV TERMINOLOGY

AC-3: Also known as Dolby Digital, a coding and compression method for surround audio capable of driving 5 speakers and a sub-woofer.

Chroma, Chrominance: The signal in an S-Video circuit that carries the color overlay information.

DBS - Direct Broadcast Satellite: The generic term for the small-dish digital systems in popular use today.

Downsampling: Reducing the information content (detail) in an image in order to allow rendering to a lower resolution display.

DTV – Digital Television: The generic term for broadcasting of any of the approved digital formats.

DVD – Digital Versatile Disk: A data encoding standard for CD-ROM-like disks, capable of storing data at the higher densities needed for recording movies.

HDTV – High Definition Television: The term which refers to those approved digital formats with resolution higher than SDTV, namely those with 720 or 1,080 vertical lines of resolution.

IEEE 1394: Also known as Firewire, a high-speed serial interconnect capable of transferring up to 400 Megabits per second.

Luma, Luminance: The signal in an S-Video circuit that carries the black-and-white detail information.

MPEG-2: A “compression” method for reducing the bit rate needed to transmit a series of images.

MSO: Multiple Services Operator – a cable TV company.

PSIP - Program and System Information Protocol: The data stream within a DTV broadcast that describes the various video, audio and data streams that are present.

QAM – Quadrature Amplitude Modulation: A method of encoding bits using multiple analog levels to represent bit patterns – often used by the cable industry.

SDTV – Standard Definition Television: The term which refers to those of the approved digital formats with resolution comparable to today’s DBS and DVD systems, namely those with 480 vertical lines of resolution.

Transcoding: Converting from one modulation method to another, for example, from VSB to QAM.

USB – Universal Serial Bus: A medium-speed (12 Megabit per second) local communication bus.

VSB – Vestigal Side-Band: A method of encoding bits used primarily by the television broadcast industry.

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