DTV Format Conversion – A Buyer's Guide

Courtesy of Teranex, Inc.
By Jed Deame
Director of Product Development
Teranex, Inc.
http://www.Teranex.com

Introduction

As the FCC deadlines for broadcast of Digital Television (DTV) arrive, broadcasters are faced with the challenge of integrating High Definition Television (HDTV) programming into their existing NTSC or 601 plants. In the early stages of the DTV rollout, broadcasters will be required to simultaneously broadcast program material on both digital and analog channels (simulcast). In addition, broadcasters will need to combine locally generated advertising, programming and logos with network generated programming. However, this material will now be in a variety of different high definition and standard definition formats. This will force the broadcaster to convert most of their material from standard definition to high definition (up-convert), from high definition to standard definition (down-convert), or from one high definition format to another (side-convert). Often all of these conversions will need to be performed simultaneously. This has created an instant need for a variety of format converters.

There is currently a lack of standardization between television networks on a common DTV distribution and transmission format. NBC and CBS have adopted the 1080-line interlaced format (1080i60), ABC is broadcasting 720-line progressive (720p60) and Fox is broadcasting 480-line progressive (480p30). These are just three of the 18 DTV formats described in the infamous ATSC Table 3 (See Figure 1), which itself was deleted from the FCC mandate so as not to overly constrain the broadcasters. In fact, the number is much higher, especially if you include the overseas 50Hz formats and any custom formats. The Direct Satellite broadcasters are experimenting with their own custom formats, as are the cable operators. Broadcasters will choose their preferred formats based on program content, multicast requirements, interactivity requirements, compatibility with existing infrastructure, and other factors. Small changes to the picture size and frame rate can free up significant bandwidth for other non-video data, such as Internet or e-commerce. The flexibility that DTV brings to the broadcaster enables them to more easily build a business model for DTV. Accordingly, this flexibility has brought with it the need for the DTV format converter.

Vertical lines	Pixels	Aspect ratio	Picture rate
1080	1920	16:9	60I, 30P, 24P
720	1280	16:9	60I, 30P, 24P
480	704	16:9 and 4:3	60P, 60I, 30P, 24P
480	640	4:3	60P, 60I, 30P, 24P

Figure 1: ATSC Table 3, The 18 DTV Formats

Format Conversion Basics

DTV format conversion is the process of converting between the 18+ formats of Standard Definition Television (SDTV) and High Definition Television (HDTV). Format converters come in many flavors such as up-converters, down-converters, side-converters, cross-converters and all-format converters. Side-converters convert between the multiple HDTV formats, for instance, 720p to 1080i or 1080i to 720p. Cross-converters are format converters that also perform frame rate conversion between 50 Hz and 60 Hz. All-format converters convert any format to any other format, often including the 50 Hz to 60 Hz conversions. A typical broadcaster or post-production facility will need a variety of format converters depending on their rollout plan. Initially, broadcasters will need an up-converter and a down-converter supporting their particular DTV emission format. Soon afterwards, they may desire to use program material from other networks, which will most likely be in a different DTV format. In that case, the broadcaster might opt for an all-format converter, which can convert any format to any other format. The post-production facilities will probably also desire the all-format converter to accommodate the variety of formats that their clients desire.

DTV System Solutions

The HDTV up-converter is an essential element in an HDTV Television station. A typical application, as diagrammed in Figure 2 below, begins with the collection of SDTV source video. The source video may come from satellite feed, archival videotape, or live studio feed.

Up-Conversion Application

- Network HDTV Pass-through with Local SDTV or HDTV Program Insertion

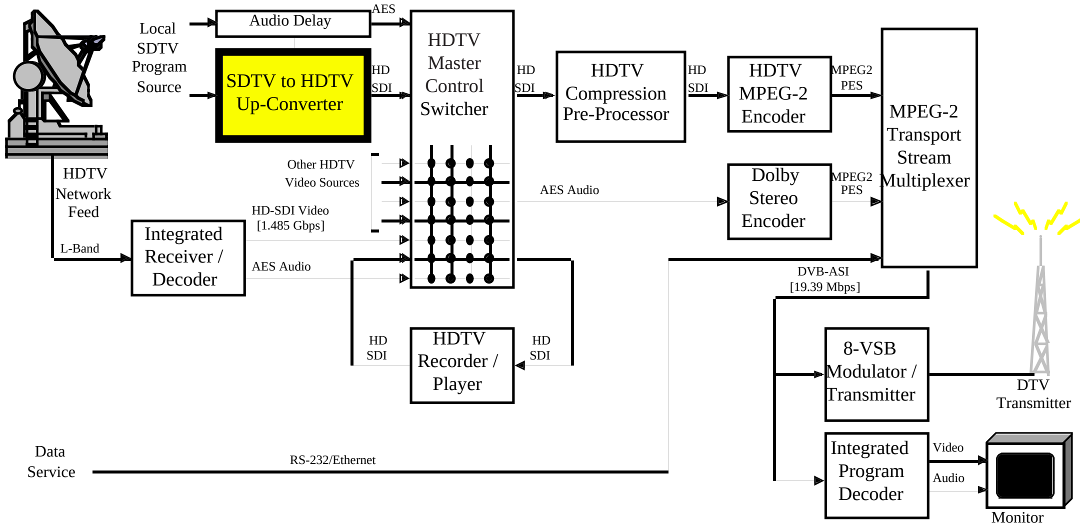

Figure 2: Up-Conversion Application

The SDTV source is converted to the internal HDTV format by the up-converter and fed to an HDTV switcher where it is mixed with HDTV source material to produce the HDTV master feed. This master feed is then fed to a compression pre-processor where the data is prepared for MPEG-2 encoding. The final stage of the HDTV processing is MPEG encoding, the process of compressing the 1.24 Gbit digital data stream into the 19.39 Mbit Transport Stream and then 8-VSB modulating to fit within the 6 MHz bandwidth of a single television channel.

Certain broadcasters may choose to down-convert the HDTV network feed so they can take advantage of their SDI or NTSC plants for processing and local program or graphic insertion. In this case, a down-converter may be used for conversion of the HDTV satellite feed to SDTV. After processing the video in the SDTV plant the video is up-converted, conditioned by a compression pre-processor, MPEG encoded, modulated, and transmitted. This process is diagrammed in Figure 3.

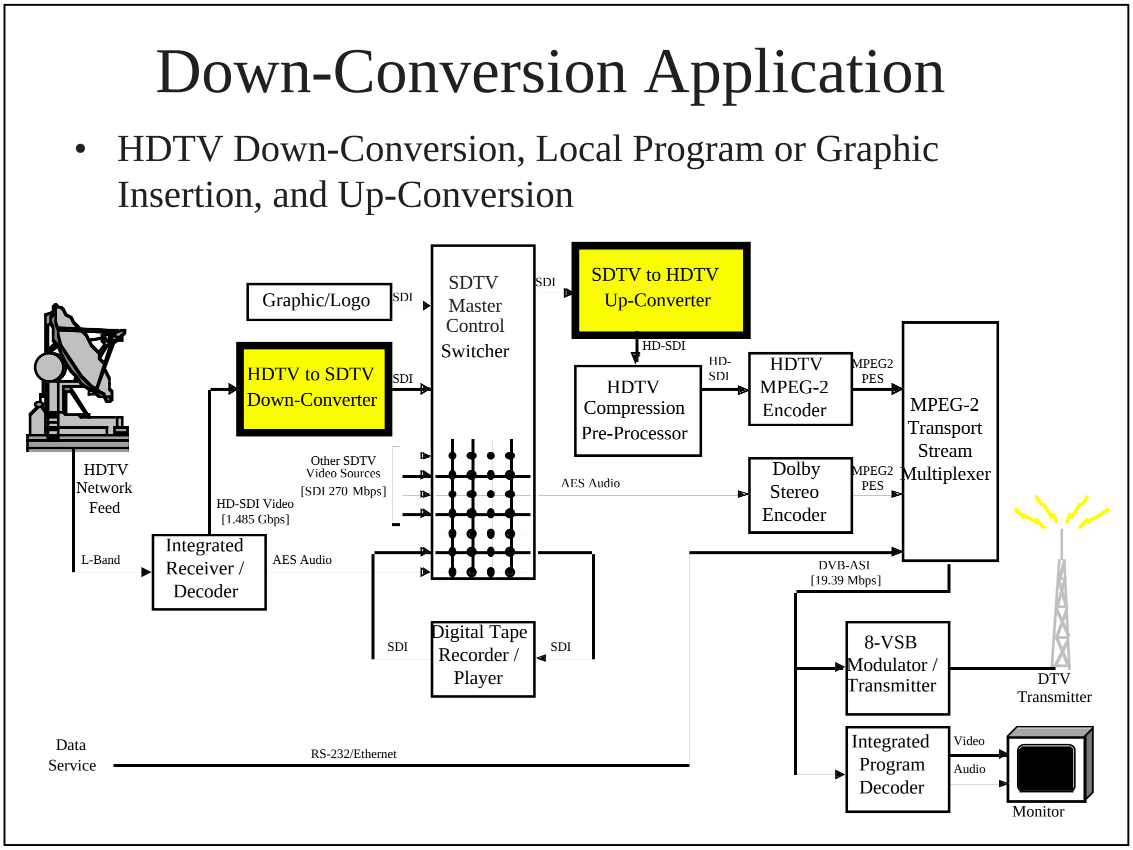

Figure 3: Down-Conversion Application

In post-production facilities, the internal HDTV format used may not be the same HDTV format desired by the customer. A side-converter or all-format converter can be used for conversion to and from the plant native HDTV format.

Format Converter Selection Criteria

The current generation of DTV up/down converters support most of the popular 30fps interlaced and 60fps progressive formats, but the equipment manufacturers have been slow to support emerging formats such as 480p30, 480p60 and 1080p24. This makes the decision of when to commit DTV format converter a daunting task for broadcasters and post houses. One important feature to look for when selecting a DTV format converter is support for current and future DTV formats such as the emerging 24 frame per second HDTV video production standard (1080p24). This appears to be evolving into the common interchange standard for HDTV material, particularly film-based material. Another feature becoming increasingly more important is frame rate conversion to support the overseas 50 Hz television systems. Also, since the number of DTV formats in use is increasing rather than decreasing, there is a significant advantage in converters that are updatable to emerging formats, so as not to obsolete the substantial investment into a converter. This “future proofing" concept is just beginning to become popular with the introduction of "universal" or "all-format" converters, which can be updated via software to support new formats. In addition to supporting the desired DTV formats, the I/O should support both SMPTE 259M SDI and SMPTE 292M HD-SDI inputs and outputs with options for 480p60 and analog formats as needed.

De-Interlacing and Re-sampling

The most important evaluation criteria, by far, is image quality. The image quality is driven by two variables: the quality of the de-interlacing algorithm, and the quality of the re-sampling algorithm. Ultimately, the final quality of the video stream is dependent upon the type and the refinement of the image processing algorithms that are applied to it. For instance, with respect to up-conversion from 480i to 720p, the first and most complex step is to convert the interlaced image to progressive (480p). This is necessary because the odd lines of the image are spatially shifted from the even lines, due to inter-field motion. This misalignment must be dealt with in order to create visually pleasing progressive images. Once a clean 480p image is created, it may then be re-sampled to the desired new image format.

There are three basic methods for de-interlacing an image. The first type of algorithm for de-interlacing is field interpolation. In this method, every other line of the input image is discarded, reducing the image size from 720x486 to 720x243. The 1/2 resolution image is then re-sampled to the desired HDTV image size. The advantage of this process is that is has minimal compute requirements. The disadvantage is that the input vertical resolution is halved before the image is scaled, thus reducing the detail in the up-converted image.

The second de-interlacing method is motion adaptive. In this method, the amount of inter-field motion is measured and used to make the decision of whether to use the entire input frame (in the case where there was no inter-field motion), or discard every other line (in the case where there was significant motion). Advanced motion adaptive techniques can vary the percentage of the previous field's data that is retained as the inter-field motion increases. The processing requirements for motion adaptive de-interlacing are higher than that of Field Interpolation, which is apparent in the output image quality. The challenge in implementing an effective Motion Adaptive algorithm is effectively dealing with the trade-off between double images (or softness) and lost vertical resolution.

The third and most advanced method of de-interlacing is motion compensation. This technique, which has successfully been used in advanced SDTV standards converters, is beginning to show up in high-end DTV format converters. Motion compensated de-interlacing measures the inter-field motion, and then aligns data between the two video fields on a pixel-by-pixel basis, maintaining the full vertical resolution of the imagery even when significant motion is detected. The biggest challenge in implementing motion compensation is the sheer processing requirement. Motion Compensated format conversion has been used in HDTV non-linear editing systems for some time, but even the most powerful workstations have been unable to process the data in real time. Fortunately, technology has advanced to a point where real-time motion compensated format conversion is possible, although this ultra-high performance comes at a premium price.

Once the image has been properly de-interlaced, it must then be re-sampled, or re-sized, to the desired output format. This process requires interpolation filters. There are two basic classes of interpolation filters: optimal, and non-optimal. Optimal filters are precisely designed in order to preserve the detail of the input imagery throughout the scaling process, whereas non-optimal filters are an approximation to the ideal (optimal) filter curves. Interpolation filter quality may also be characterized by the filter size, or number of taps. As the number of taps in an interpolation filter increases, more surrounding pixels are used to generate the resultant pixel value, increasing the accuracy of the interpolation. With respect to filter size, there is a practical limit to the number of taps required to perform the re-sampling, after which adding additional taps has negligible effects.

Getting the Colors Right

Another important step in the format conversion process is colorspace conversion. This is the process of changing the RGB primaries and the white point to account for the differences in the standards. In particular, the conversion from ITU-R BT.601 SDTV images to SMPTE 274M HDTV images requires a manipulation of the color matrices to account for, among other things, the different phosphors used in HDTV monitors. There are two basic methods for performing colorspace conversion. The first, and simplest approach, is to convert between two non-linear, gamma corrected with a linear transformation. This technique can introduce errors, up to 20% on some material, because linear operations are being applied to non-linear coordinates. On most material the error is small, and the results may be acceptable to many users. High-end format converters use a second technique, which is to convert the source gamma corrected, non-linear colorspace to its un-gamma corrected, linear colorspace before manipulating the color matrices. This allows the linear transformation to be applied to a linear colorspace. The destination linear colorspace is then gamma corrected to match the gamma requirements of the destination display. This process provides negligible error in the conversion, but is significantly more complex to implement.

Conclusion

The process of DTV format conversion is essential to enabling the interchange of digital television material in this new digital era. The days of simply connecting a coax cable between two incompatible VTRs are disappearing fast. The enormous flexibility provided by digital television provides numerous benefits, but it also has its costs. In particular, black box format converters will need to be installed in most facilities to accommodate the variety of material that might enter or leave the facility. These devices will enable broadcasters and post-production facilities to gracefully transition into the world of DTV, leveraging their current program material and equipment investments for as long as possible.

References

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