Will Widescreen (16:9) Work Over Cable?

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Digital video, in both standard definition and high definition, is rapidly setting the standard for the highest quality television viewing experience. Digital Versatile Disc (DVD) is already delivering standard definition digital video in both 4:3 and 16:9 aspect ratios for display on existing NTSC television sets. High Definition Television will extend this experience delivering both of these aspect ratios and significantly higher resolutions. The desire for consumers to watch movies in either letterbox or pan-and-scan format depending on their preferences will push the Cable Industry to support both these aspect ratios. However, there are a number of technical issues that make this problematic. This paper will explore the technical issues surrounding dual aspect ratios and offer possible solutions to them.

INTRODUCTION

With the advent of MPEG video compression the ability to deliver more video content at various resolutions and aspect ratios has become a reality. The MPEG video compression standard [1] allows for both standard definition and high definition resolutions. Standard Definition Television (SDTV) is specifically formatted to work with today's NTSC and PAL television sets. High Definition Television (HDTV) is specifically formatted High Definition television sets that will be commercially available later this year.

SDTV is being delivered today via cable, satellite, and Digital Versatile Disc (DVD) [2]. HDTV broadcast is currently being tested and will begin on a national basis later this year. Aside from the issues of which specific HDTV formats will be used, there is the issue of how the multiple aspect ratios of movies and video material will be presented on the subscriber's television. This is particularly an issue for network operators, as it affects bandwidth efficiency and customer expectation.

The Advanced Television Systems Committee [3] has specified 18 different standard formats for digital television covering frame rate, picture resolution, scan mode, and aspect ratio. These 18 formats specify two aspect ratios, 4:3 and 16:9, and four resolutions covering both SDTV and HDTV display.

Aspect Ratio and Resolution

Aspect ratio is defined as the ratio of the width to the height of the source material or the display device. Typically, this is expressed as "*width*:*height*" or as the fraction *width/height*. Resolution (the number of picture elements, or pixels, displayed on the screen) is typically expressed as "*width* x *height*". The higher the resolution, the sharper the image appears on the display.

Table 1 below provides a list of some of the common aspect ratios and resolutions used in digital television.

Aspect Ratio or Resolution	Fraction	Description
16:9	1.778	HD TVs and widescreen SD TVs
4:3	1.333	Most SD TVs
1920x1080	1.778	HDTV
1280x720	1.778	HDTV
704x480	1.467	SDTV
640x480	1.333	SDTV

Table 1 - Common Digital Television Aspect Ratios and Resolutions

When square pixels are used, the resolution and aspect ratio are the same when expressed as a fraction. Square pixels are of importance to the computer graphics industry, however, in MPEG video there is no requirement to use square pixels.

For the source image to be displayed without distortion on the display device, it is necessary that the source aspect ratio match the display device aspect ratio. A mismatch of the source and display aspect ratios will result in a squeezing or stretching of the image itself. The greater the mismatch in aspect ratios the more noticeable this distortion will be. When one considers the historical evolution of motion pictures, this has become a more significant issue.

The aspect ratios of motion pictures over the years has spanned the range from 1.33:1 to 2.76:1, with 1.85:1 and 2.35:1 being the most common aspect ratios being used today [4,5]. Table 2 below provides examples of common motion picture aspect ratios.

Aspect Ratio	Fraction	Description
16.7:9	1.85	35 mm movies
19.9:9	2.21	70 mm movies
21.2:9	2.35	Panavision, Cinemascope
24.3:9	2.7	Ultra Panavision

Table 2 - Common Movie Aspect Ratios

Most of us are familiar with the tall and skinny pictures from movies not displayed at the proper aspect ratio. Figure 1 shows an example of this distortion. This sometimes occurs as the credits roll at either the start or end of the movie.

Figure 1 - Aspect Ratio Distortion [6]

As can be seen from tables 1 and 2 above, none of the common movie aspect ratios match either the SDTV or HDTV aspect ratios. This presents the problem of how to display an undistorted movie image on either of these types of television sets.

Pan & Scan versus Letterbox

Since aspect ratio must be preserved in order to prevent distortion of the resulting image, we have the problem of presenting movie material on either a 4:3 or 16:9 display. There are two methods used to address this problem when transferring a movie title for television display. One can either use Letterbox or Pan & Scan transfer on a 4:3 television.

In Letterbox transfer the full movie aspect ratio is presented, however, black bars are displayed at the top and bottom of the television to enable it to fit the 4:3 TV aspect ratio. Figure 2 is an example of Letterbox transfer.

In Pan & Scan transfer a 4:3 window is placed over the full movie material. This 4:3 window is moved horizontally or vertically, zoomed in or out, as necessary to capture the “important” portion of each frame of the movie.. The determination of what is the “important” portion of each frame varies from film to film and director to director. Some directors are particularly sensitive to the cinematic effect of the wider aspect ratios of motion pictures and take a more active role in recomposing the film in its 4:3 Pan & Scan version. Figure 3 shows an example of Pan & Scan transfer.

In the case of 16:9 encoded MPEG material the movement of this 4:3 window is captured by the Pan & Scan vector and transmitted along with the MPEG video data, however, the MPEG Pan & Scan vector is limited to horizontal movement only. As we will see shortly, this limitation is an issue for the usage of the MPEG Pan & Scan vector.

Notice that the figure on the right in the Letterbox example is not visible in the Pan & Scan example. This is an objection to Pan & Scan transfer. The black bars above and below the image in the Letterbox example is an objection to Letterbox transfer.

Letterbox display is less objectionable on 16:9 television displays than it is on 4:3 television displays as motion picture aspect ratios more closely match this larger aspect ratio. The black bars above and below the image are much narrower on a 16:9 television. Table 3 below shows the percentage of the display space that is used for the image in Letterbox mode on either a 4:3 or 16:9 display for source material of several aspect ratios. In general, a much greater percentage of the display is used when its aspect ratio is 16:9.

Figure 2 - Example of Letterbox

Figure 3 - Example of Pan & Scan

Display aspect ratio	Source Aspect Ratio		
	1.33	1.85	2.35
4:3	100%	72%	57%
16:9	75%	96%	76%

Table 3 - Display usage for Letterbox

The problems of dual aspect ratios are different for SDTV than it is for HDTV. The remainder of this paper will address the respective problems of transmitting movie material for SDTV and HDTV.

STANDARD DEFINITION TELEVISION

The problem for transmission of SDTV resolution MPEG video relates to having two different aspect ratios for standard definition television sets, either 4:3 or 16:9. A majority of televisions in the US today are of the 4:3 aspect ratio, however, a number of television manufacturers have been producing widescreen televisions that have a 16:9 aspect ratio. These widescreen televisions have a number of operating modes that will be discussed shortly.

For optimal display on both types of televisions you might wish to use Pan & Scan on the 4:3 TV and Letterbox on the 16:9 TV. The viewer may wish to determine which version of the film they watch as well. One viewer may wish to watch a movie in Pan & Scan on his 4:3 television and another viewer may wish to watch it in Letterbox. Ideally, the network operator would prefer to support both of these viewers with a single MPEG video stream. It is more bandwidth efficient to broadcast only one MPEG video stream for both types of displays.

To understand the issues with dual aspect ratio on SDTV it is necessary to understand the behavior of both 4:3 and widescreen televisions having a 16:9 aspect ratio. The behavior of 4:3 televisions is simple, they only have one mode of operation. Widescreen televisions have multiple modes of operation.

The Behavior of Widescreen (16:9) Televisions

Several television manufactures build widescreen (16:9) televisions for the US market and widescreen televisions are already widely accepted in Japan and Europe. Examples of widescreen NTSC televisions include: Pioneer's Elite PRO-119, Toshiba's TW40F80 and TW65G80, JVC's NV55BH6, and Goldstar's WF-32A10S). These TVs all support at least three modes of operation:

1. NORMAL mode - in this mode the TV displays standard 4:3 television images on a 16:9 screen with black side bars to preserve aspect ratio
2. THEATERWIDE or CINEMA WIDE mode - in this mode the TV would provide virtually full-screen images of Letterbox formatted video tapes, laser disks, or DVD material by expanding it vertically to maximize the display. Some 16:9 TVs have multiples of this version to adapt to a variety of Letterbox aspect ratios.
3. FULL or CINEMA FULL mode - in this mode the TV would expect 16:9 material anamorphically squeezed into a 4:3 format and display the full 16:9 material at the proper aspect ratio.

Another issue for SDTV is how the MPEG decoding device (set-top, DVD player, or satellite IRD) signals the widescreen television the appropriate mode (NORMAL or FULL) is to be used. This is less of an issue for DVD players as the user will likely set up the DVD player to operate in one mode and leave it that way. For a set-top or satellite IRD the user will be changing between channels with 4:3 and 16:9 source material, causing a need to signal the TV potentially at each channel change.

In addition to the issues for the television viewer, there are the concerns of movie studios and directors regarding the presentation of their creative material.

Issues for the studios and directors

Ideally, the network operator could broadcast one MPEG program stream of the movie material with the appropriate Pan & Scan vector information for 4:3 display. In this way the owner of a widescreen TV could view the 16:9 movie and the owner of a 4:3 TV could view this either in Letterbox or in Pan & Scan according to their preference. However, there are a number of concerns among the movie studios and directors that make this undesirable from their perspective.

The first of these is the loss of resolution in 4:3 Pan & Scan mode. If the original source material is encoded at a 704x480 resolution at 16:9 aspect ratio, then the 4:3 Pan & Scan image will have a 25% reduction in resolution resulting in a 528x480 display resolution.

The second and more important problem is that the MPEG Pan & Scan vector is limited to horizontal movement only, however, in general when a Pan & Scan transfer is made to video tape, vertical movement and zooming are also used to provide the "best" representation of the cinematic mode the director intended to create. Frequently, the movie director will retain control of the Pan & Scan transfer for this reason.

Solutions for SDTV

Given the studios objections to the use of the MPEG Pan & Scan vector, it really is necessary to transmit two versions of the same movie. One version transmitted in Letterbox for 16:9 televisions and one version transmitted in Pan & Scan for 4:3 televisions. DVD also uses this dual stream solution. Typically a DVD title will come with two sides. The first side will contain the Pan & Scan transfer for 4:3 display and the second side will contain the Letterbox transfer for 16:9 display. The viewer can choose which to view and how to display them. The only realistic option for cable broadcast is to simulcast both the 4:3 Pan & Scan and the 16:9 Letterbox versions of the video together with only one set of audio streams shared between the two video streams.

HIGH DEFINITION TELEVISION

Since High Definition televisions have only one aspect ratio and it is 16:9, they do not share the problems of Standard Definition televisions having two aspect ratios. HDTV presents a different problem for network operators. The memory and MPEG decoder performance required for HDTV decode is substantially greater than for SDTV and consequently more costly. Network operators currently incur the burden of the set-top terminal cost. They purchase the set-top terminals that are installed in subscribers homes and are unlikely to take on the additional cost of HDTV decode without a corresponding increase in revenue.

High Definition televisions will already contain the memory and MPEG decoder performance required to decode HDTV. The subscriber will already have purchased this equipment and it is redundant to have the same capability built into the set-top terminal. This necessitates a digital interconnect between the set-top terminal and the High Definition television to pass the uncompressed MPEG data. The set-top then functions as the tuner, QAM demodulator, and PID filter to direct the proper MPEG program stream to the digital interface. Today, the digital interconnect most commonly being considered is IEEE 1394.

The use of a 1394 interface between the set-top terminal and the High Definition television solves one problem, but introduces two additional issues. The first is tht transmission of HDTV MPEG in the clear across an open interface, such as 1394, permits anyone to make an unlimited number of perfect copies of the original source material. This ability to make unlimited copies is of even greater concern to the studios than the issues for 4:3 Pan & Scan transfer for SDTV. The second issue is presentation of the user interface (UI) generated by the set-top terminal. Since the HDTV is performing the MPEG decompression and not the set-top terminal, the ability for the set-top to composite the UI on top of the video has been lost. A protocol must be defined to transmit the set-top generated UI to the HDTV which must perform the process of combining the UI with the decompressed MPEG video.

Solutions for HDTV

The Motion Picture Association of America (MPAA) has required that there be an acceptable form of digital copy protection placed on common interfaces, such as 1394. There has recently been an agreement between Sony and Intel, the two leading vendors of copy protection technology to merge their copy protection schemes into a single 1394 digital copy protection standard. To date, there has been no well organized effort to define the UI presentation protocol between the set-top terminal and the HDTV over 1394.

Once the digital copy protection compromise and the UI presentation protocol have been implemented, it will be possible to interconnect digital set-top terminals to High Definition televisions using 1394.

CONCLUSIONS

The network operator must consider how do deal with the dual aspect ratio of the 18 ATSC digital TV formats. For SDTV there are two options, either simulcast both a 4:3 and a 16:9 version of the video stream or broadcast only the 4:3 version. For HDTV finalizing the digital copy protection mechanism and UI presentation protocol will enable carriage of HD content over cable.

Given the relative low penetration of standard definition widescreen televisions, it is unlikely that network operators and satellite providers will dual carry movies in both 4:3 Pan & Scan and 16:9 Letterbox format to accommodate both aspect ratios. With the national deployment of HDTV later this year it makes more sense to wait for this deployment to support movie material in its original theatrical aspect ratio.

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