Canceling the Postage Stamp: AFD, Bar Data and Pan-Scan

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We are all familiar by now with one of the unfortunate side effects of the transition from the 4x3 aspect ratio of NTSC to the 16x9 aspect ratio of high- and extended-definition television, the tiny image in the center of the screen, surrounded by black bars on all sides. This is the dreaded "postage stamp", detested equally by content creators, broadcasters, viewers and consumer electronics manufacturers. What's the point of having a large display, after all, if you're going to fill half the screen area with black bars?

It would be nice if we could wave a magic wand and consign all 4x3 images and displays to the dustbin of history, but that's not going to happen. Legacy programming will be with us seemingly forever; good shows will attract an audience no matter in what aspect ratio they were shot, and legacy 4x3 displays will have a significant lifetime after the turnoff of analog broadcasting in 2009. We need something better than a stopgap solution. Creating images for display in more than one aspect ratio always involves compromises, as any cinematographer will tell you, so any solution we devise will not be a panacea. However, with some ingenuity we can solve most of the problems routinely encountered.

Elements of the problem have been addressed before in a number of organizations. Recognizing the need for a comprehensive end-to-end solution, ATSC, CEA and SMPTE agreed to work together to ensure development of a harmonized set of standards and recommendations to cover both HD and SD signals, applicable in the production facility, the broadcast plant and the home receiver and display. The author has been an active participant in all three groups.

This paper describes three tools, Active Format Description (AFD), Bar Data and Pan-Scan. AFD and Bar Data are intended to be conveyed the entire length of the image "food chain", being finally used in the consumer receiver and display. Because they are so closely related, in the SMPTE standard AFD and Bar Data are carried in a single data structure. Pan-Scan, by contrast, is intended for use only in the professional space, allowing intelligent control of downstream aspect ratio and image format converters based on information embedded in the video signal at the point of creative control. All three are frame-based, so the display of the signal can be changed on a frame-by-frame basis.

AFD

The problem of optimizing display of 4:3 and 16:9 images on displays of both aspect ratios simultaneously was first dealt with in Europe, where both the UK and Sweden independently devised solutions. The two proposals were reconciled; the result was called AFD, Active Format Description.

AFD is documented in Annex B of the DVB Implementation Guidelines, ETSI TS 101 154. It is a four-bit field, capable of signaling up to 16 different states. Not all of these are used, however. Instead, the two sets of solutions were aligned so that minimal adverse impact would occur if the MSB were dropped, since the original UK equipment dealt only with the three LSBs. For more background, see *Digital Receiver Implementation Guidelines and Recommended Receiver Reaction to Aspect Ratio Signaling in Digital Video Broadcasting.* Only ten of the possible 16 states are defined; of these ten, only nine are recommended for use in the US. See CEB16 for details of US usage.

Carriage of AFD in digital broadcasts is defined in ISO/IEC 13818-2 (MPEG-2 video.) The ATSC digital transmission standard A/53D supports this, as do the proposals for the advanced video codecs AVC and VC-1. Carriage of AFD over uncompressed digital video interfaces was defined only for standard definition; for production purposes in the UK, a modification was made to SMPTE RP 186, Video Index, to allow carriage in uncompressed digital standard-definition signals of the three LSBs of AFD. The resulting document is referred to in Europe as RP 186bis. A compatible revision of RP 186 is underway in SMPTE; this will permit carriage of all four bits. However, RP 186 is usable only for standard-definition digital signals and the interface is not widely supported. A solution is needed that will work for all image formats, both standard- and high-definition, over all professional video interfaces, especially SMPTE 259M (SDI) and SMPTE 292M (HD-SDI.)

At the same time, receiver manufacturers need to understand how to interpret the AFD data and use it to control the scaling engines found in modern TV set-top boxes and displays; this is not as straightforward as it may seem, because the set-top and display may be separate devices and may or may not implement widescreen signaling (WSS) in the connection between them. The forthcoming Consumer Electronics Bulletin CEB 16 spells out in detail the appropriate responses of both receivers and displays to AFD as well as Bar Data.

Table 1 lists the AFD codes recommended for use in the United States. Note that in some cases the meaning of AFD is dependent on the aspect ratio of the frame; for ATSC emission, this is the aspect ratio of the coded frame.

Code	In a 4:3 Frame	In a 16:9 Frame
0000	AFD Undefined	AFD Undefined
0001	Reserved	Reserved
0010	Not recommended	Not recommended
0011	Not recommended	Not recommended
0100	Letterbox image with aspect ratio greater than 16:9	Letterbox image with an aspect ratio greater than 16:9
0101	Reserved	Reserved
0110	Reserved	Reserved
0111	Reserved	Reserved
1000	Full-frame 4:3 image, same as coded frame	Full frame 16:9 image, same as coded frame
1001	Full-frame 4:3 image	Pillarbox 4:3 image
1010	Letterbox 16:9 image vertically centered in the frame	Full-frame 16:9 image
1011	Letterbox 14:9 image vertically centered in the frame	Pillarbox 14:9 image horizontally centered in the frame
1100	Reserved	Reserved
1101	Full-frame 4:3 image with alternate 14:9 center	Pillarbox 4:3 image with alternate 14:9 center
1110	Letterbox 16:9 image with alternate 14:9 center	Full-frame image with alternate 14:9 center
1111	Letterbox 16:9 image with alternate 4:3 center	Full-frame 16:9 image with alternate 4:3 center

Table 1. AFD Codes

AFD 0000 indicates that AFD information is unavailable; the image should be interpreted to be the same as the coded frame unless Bar Data is present. If Bar Data is present, it should be used. See the discussion of Bar Data below.

AFD 0100 differs from the others in that it is expected to be accompanied by Bar Data. This code is for use with images whose aspect ratio is wider than 16:9, primarily widescreen theatrical features. The Bar Data specifies the height of the letterbox bars; these cannot be determined from AFD alone, as the aspect ratio of the image cannot be directly specified with AFD. If Bar Data is missing, the image is presumed to be 16:9.

AFD 1011 refers to a 14:9 image. Nobody makes a camera that creates 14:9 images, and nobody makes a 14:9 consumer television display. The 14:9 aspect ratio is midway between 4:3 and 16:9; 14:9 images are created by cropping off the extreme upper and lower edges of a 4:3 image or the extreme left and right edges of a 16:9 image in an aspect ratio converter. The result contains nearly all the information of the original image, but can be shown on either a 4:3 or 16:9 display with the addition of thin bars, pillarbox bars for 16:9 displays and letterbox bars for 4:3 displays. Use of 14:9 is controversial; some consider it a useful compromise, while others consider it at best an unnecessary complication and at worst a perversion of artistic intent.

AFDs 1101 through 1111 are used with “shoot and protect” images; those where the image has been composed so that its edges (top and bottom for 4:3, left and right for 16:9) can be cropped off without loss of essential program information. Use of these codes signals to the receiver/display that it can safely perform a center cut and zoom out to minimize (AFD 1101 and 1110) or eliminate (AFD 1111) any bars when presenting the image on a display of the other aspect ratio.

When used in a compressed bitstream, the aspect ratio of the coded images can be determined from inspection of the bitstream. However, in the case of 480-line images, the aspect ratio cannot be determined this way, so the SMPTE standard includes means to signal this parameter.

If AFD and Bar Data are both present, the receiver/display should use AFD alone except in the cases of AFD 0000, where Bar Data should be used, and AFD 0100, where Bar Data supplements the AFD information.

BAR DATA

Bar Data was originally developed by ATSC to signal the extent of any bars, whether letterbox or pillarbox, that had been appended to the image when converted to a different aspect ratio. At the time, the intent was to allow the display to backfill these areas with neutral grey in an effort to minimize uneven screen aging. Recent developments in displays have rendered this application largely moot. However, other developments, including selective backlighting on transmissive displays, offer the opportunity to enhance the viewing experience, especially in darkened media rooms.

The most useful application of Bar Data is to signal to the receiver the exact vertical extent and placement of high-definition images of aspect ratios greater than 16:9, as signaled by AFD 0100. Several widescreen aspect ratios are in use for theatrical features. The most common is 2.39:1. SMPTE RP 199 makes recommendations on how these are to be transferred to high-definition television signals in order to preserve the original aspect ratio of the work.

Bar Data, if present, contains exactly one pair of bars, either top and bottom (letterbox bars) or left and right (pillarbox bars.) The Bar Data signals the inner extent of the bars; for example, the top_bar parameter gives the last line of the top bar, while the bottom_bar parameter gives the top line of the bottom bar. The bars need not be of equal size. The precise definition and syntax is given in ATSC A/53. This is under revision; see ATSC Candidate Standard CS/TSG-674.

Let us see how Bar Data can be used in conjunction with AFD 0100 to specify the position of a widescreen image in a 16:9 frame. It is normal practice, though not required, to center the image vertically in the frame, so we want the bar sizes to be equal. From Table 1 of RP 199, we see that a 2.39:1 image should be 803 lines high in a 1920 x 1080 frame and 536 lines high in a 1280 x 720 frame. Therefore, if we wish to present a widescreen feature in 720P, the total height of the two bars will be 720 - 536 or 184 lines, so each bar will be 92 lines high. The line numbers as given in SMPTE RP 202 are referenced to the standard for the source image, which in this case is SMPTE 296M. RP 202 tells us that the first line of the 720 in the frame (in SMPTE terms, the active video) is Line 26 and the last is Line 745. Therefore, the bottom of the top bar is 26 - 1 + 92 or Line 117, and the top of the bottom bar is 117 + 536 + 1 or Line 654. See Figure 1.

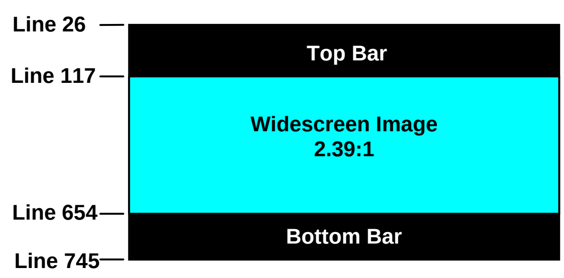

Figure 1. Bar Data Example

As noted above, if both AFD and Bar Data are present in the received signal and the AFD is any of the other defined states, the receiver should ignore the Bar Data and follow the AFD. However, if it is desired to use Bar Data for some reason, possibly the presentation of an old film using an oddball narrow aspect ratio, this can be done by transmitting AFD 0000, signaling that the Bar Data should be used to interpret the image.

Bar Data, while having more resolution than AFD, is not necessarily more accurate. In fact, in the case of 480-line frames, Bar Data may be less accurate. This is because it is inserted near the beginning of the process, most likely at the point of post-production, and the operator and equipment at that stage have no knowledge or control of the emission encoder. For 1080 and 720 line video, all video compressors encode the same set of lines. However, because SD video isn't 480 lines but 481, 483 or 486, depending on who you ask, there is no guarantee that the emission encoder is set to encode Lines 23-262 and 286-525 as specified in SMPTE RP 202, Video Alignment for MPEG-2 coding. The receiver, however, has only the coded frame to work with, and it must assume that RP 202 has been followed, so it is quite possible that the area between the bars may be offset one or more lines from the actual image in the coded frame.

PAN-SCAN

Pan-Scan data is different from the preceding two tools in that it is not intended for emission; it is for professional use within the production chain and broadcast plant. It has its roots in the pan and scan parameters in SMPTE RP 186; these were originally designed for both HD and SD video, but ended up being documented only for SD. They allowed not only for horizontal pan, but for vertical tilt and for zoom, and were conceived as a mechanism to allow an SD window, or viewport, which could be moved and resized on a frame-by-frame basis over an HD video stream, to be encoded where artistic resources were available and used downstream at multiple locations to drive downconverters. To the author's knowledge, this was done at only one network. The restriction of the system to SD was likely responsible for its limited use.

The Pan-Scan parameters currently being standardized by SMPTE do not share this limitation. Furthermore, because sufficient space is available, the zoom parameters are not multiplexed. There are other significant differences as well.

In the SMPTE standard, five elements make up the Pan-Scan data structure. These are:

- Pan-Scan data flags (4 bits) and aspect ratio code (3 bits)
- Horizontal viewport offset (16 bits)
- Vertical viewport offset (16 bits)
- Vertical size coefficient (14 bits)
- Horizontal size coefficient (14 bits)

The four flag bits, when set to one, each signal the presence of one of the four offset or size parameters. If all four are set to zero, Pan-Scan is turned off. The three-bit aspect ratio code can represent up to eight aspect ratios; five are defined, as shown in Table 2.

Code	Aspect Ratio	Description and Application
000	Undefined	
001	1.33 (4:3)	Video
010	1.56 (14:9)	Video
011	1.78 (16:9)	Video
100	1.85	Film format widescreen standard (flat)
101	2.39	Film format widescreen anamorphic
110	Undefined	
111	Undefined	

Table 2. Pan-Scan Aspect Ratio Codes

The remaining four elements define the viewport with respect to the source image. Horizontal and vertical offset are 16 bit signed numbers with four bits of sub-pixel resolution. Offset is measured from the center of the viewport relative to the center of the source image. Vertical image size is a 14 bit unsigned integer that gives the height of the viewport in source image lines. Similarly, horizontal image size is a 14 bit unsigned integer that gives the width of the viewport in source image pixels. See Figure 2. The viewport may be larger or smaller than the source image; it may also have unequal horizontal and vertical zoom ratios. The four bits of sub-pixel resolution in the horizontal and vertical offset parameters permit smooth slow pans and tilts.

Note that the output of an image converter being driven by Pan-Scan data may not be a full-frame 4:3 or 16:9 image. It is the responsibility of the converter to add any needed pillarbox or letterbox bars to the image and generate and insert the appropriate AFD and Bar Data needed by downstream devices.

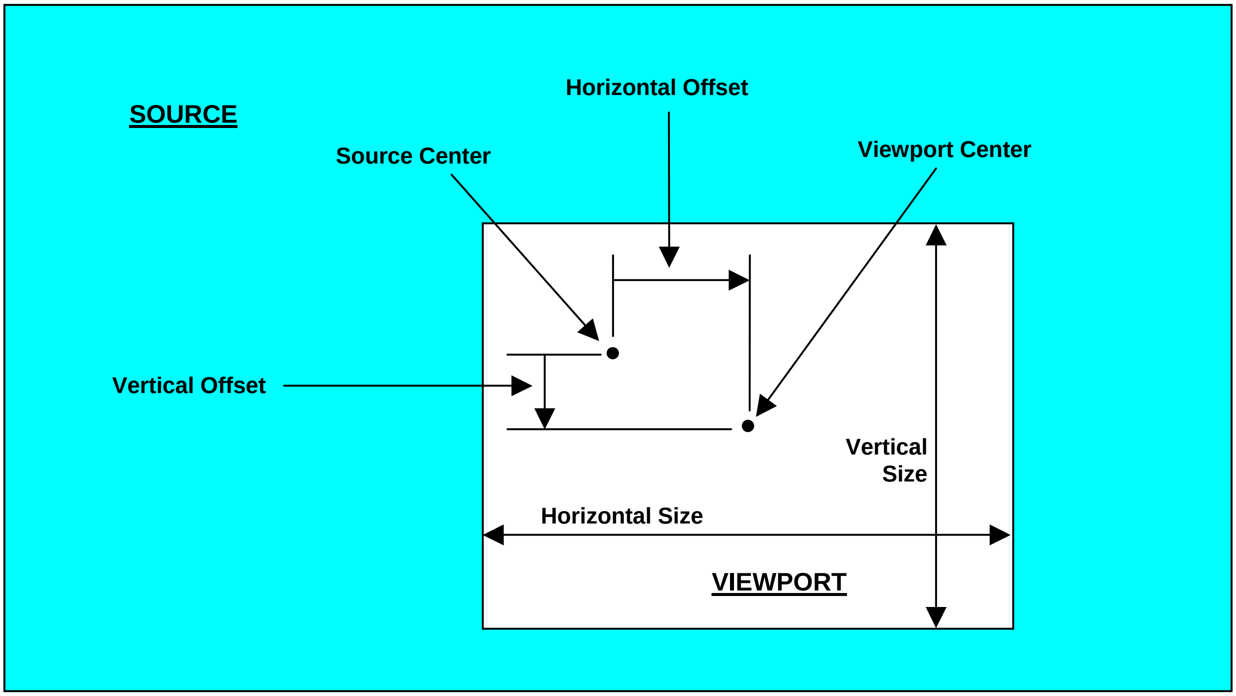

Figure 2. Pan-Scan Parameters

CONCLUSION

The "postage stamp" can be cancelled. The tools described here, AFD, Bar Data and Pan-Scan, will provide and end-to-end solution to this and other problems routinely encountered in the multiple-aspect-ratio environment with which we will all have to contend for some years into the future. The cooperation of ATSC, CEA and SMPTE, the three organizations that develop the standards for digital TV in the United States (and other countries), ensures that the information encoded in the production process can be consistently interpreted through distribution, emission and reception.

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REFERENCES

ATSC CS/TSG-674, *Candidate Standard: Draft Amendment to ATSC Digital Television Standard, Doc. A/53D Annex A*

CEA CEB-16, *Active Format Description (AFD) Recommended Practice* (in preparation)

ETSI TS 101 154 v1.7.7 (2005-1), *Digital Video Broadcasting (DVB); Implementation Guidelines for the use of Video and Audio Coding in Broadcasting Applications based on the MPEG-2 Transport Stream*

SMPTE 296M-2001, *1280 x 720 Progressive Image Sample Structure — Analog and Digital Representation and Analog Interface*

SMPTE RP 199-2004, *Mapping of Pictures in Wide-Screen (16:9) Scanning Structure to Retain Original Aspect Ratio of the Work*

SMPTE RP 202-2000, *Video Alignment for MPEG-2 coding*

Digital Receiver Implementation Guidelines and Recommended Receiver Reaction to Aspect Ratio Signaling in Digital Video Broadcasting, Issue 1.2.1, February 2001, Digital TV Group. http://www.dtg.org.uk/publications/books/afd.pdf