Stereoscopic 3D Video in the Home

Many consumers are looking with interest at all the 3D TV and projector models that are now becoming available to them, and most of them hope that they don't need to replace all their video equipment to gain 3D playback capabilities. When your clients ask you whether any of their current video equipment can work for watching 3D movies, or when they ask you for recommendations for purchasing new 3D video equipment, do you feel comfortable with your answers? Or, when you install 3D equipment for a client, but you don't get 3D pictures, do you know how to quickly get back to the happy installer/happy client mode?

Consumer Stereoscopic 3D

The new 3D-compatible consumer video displays operate in standard 2D mode when presented with a 2D video signal. But, when presented with a 3D video signal, the displays present image frames in 3D frame sequential mode (displaying alternating left and right eye image frames) and also control active LCD shutter glasses, which determine which eye sees the image being exhibited at the moment, creating a stereoscopic image.

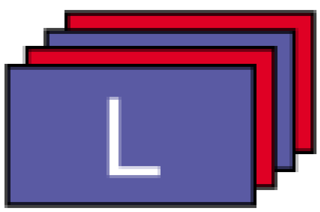

Figure 1: 3D-compatible consumer video displays produce alternating left and right eye image frames for viewing through active shutter glasses.

However, the 3D input signal to the TV is normally something other than a frame sequential 3D video format structure. These different 3D video format structures, as provided by the HDMI 1.4a spec, are different signal packaging methods used to produce, record, and convey 3D digital video signals to the home. Blu-ray, satellite, cable, terrestrial broadcast and video gaming devices use different 3D video format structures to take best advantage of their individual capabilities and limitations. The HDMI 1.4a specification details three mandatory 3D video format structures. No matter which 3D video structure is sent, though, all current consumer 3D displays convert the incoming 3D images into frame sequential left and right eye images for viewing through active shutter glasses.

HDMI 1.4a 3D Mandatory Structures

The mandatory *Frame Packing* 3D video format structure conveys two "full resolution" 1080p video signals, one for each eye. This *Full High Definition 3D* (FHD3D) signal structure specifies a 1920x2205 pixel total frame area that is larger vertically than 2D HDTV frames. Each large frame contains a left eye 1920x1080 image and a right eye 1920x1080 image over and under each other, with 45 pixels of active blanking space separating the left and right images, for progressive, or left and right odd and even fields making up full left and right 1920x1080 frames, for interlaced. Only new HDMI 1.4a compliant 3D TVs, projectors, Blu-ray players and game consoles support this Full High Definition 3D (FHD3D) signal structure, with full 1920x1080 resolution for each eye.

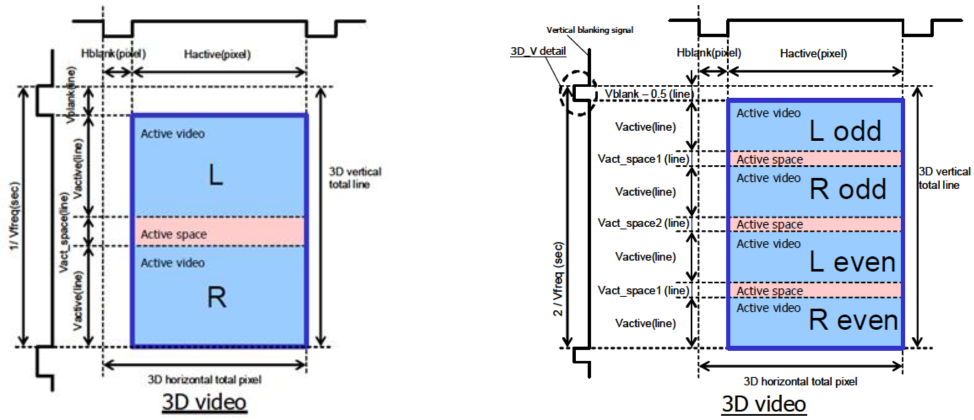

Figure 2: The Frame Packing 3D video format structure is shown on the left for progressive formats and on the right for interlaced formats.

All 3D Blu-ray players output FHD3D movies at 24 frames per second (fps), progressive. Most first generation FH3D LCD, LED backlit LCD, and plasma HDTVs internally convert 3D Blu-ray movies from “frame packing” signals to frame sequential display at 120 Hz or 240Hz (alternating left and right frames), synchronizing active shutter glasses to provide 60 or 120 frames per second for each eye.

The mandatory *Side-by-Side (Half)* and *Top-and-Bottom* 3D video format structures are “frame compatible.” These structures combine left- and right-eye signals into standard 2D HDTV video frames. This potentially allows legacy HDMI 1.3 compatible devices to support 3D video (usually with a firmware update; companies are promising to update current cable and satellite set top boxes). The firmware updates will enable the devices to produce the required HDMI 3D infoframe metadata. The advantage of these frame compatible 3D video structures is that they enable cable, satellite, and terrestrial broadcasters to transmit 3D video to their customers through their existing infrastructure, because they use the same bandwidth as regular HD content.

The Side-by-Side (Half) structure has down-sampled half horizontal resolution (960x1080 pixels for each image) so that the left- and right-eye images can be squeezed into a single 1920x1080 standard HD frame. The Top-and-Bottom structure has down-sampled half vertical resolution (1920x540 pixels for each image). In each case, a 3D display expands these lower-resolution images into full-size images, at the display’s native resolution, and presents them as frame sequential left and right eye images for viewing through active shutter glasses.

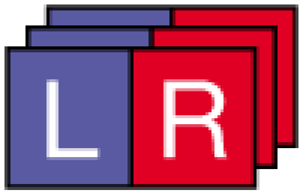

Figure 3: Side-by-Side (Half) - The left and right eye images are down-sampled horizontally, and placed in the left half and right half of the frame. This preserves the vertical resolution of the images but reduces the horizontal resolution.

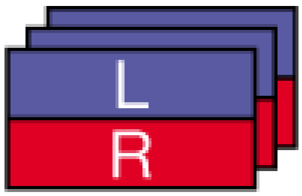

Figure 4: Top-and-Bottom - The left and right eye images are down-sampled vertically, and placed in the top and bottom of the frame. This preserves the horizontal resolution of the images but reduces the vertical resolution.

The disadvantage that cable, satellite, and terrestrial broadcasters will have with frame compatible 3D video structures is that their 3D programs will be at a lower resolution compared to the Full High Definition 3D 1080p resolution offered by new 3D Blu-ray players.

HDMI 1.4a 3D Discretionary Structures

The HDMI 1.4a spec also provides for five discretionary 3D video format structures. It seems that there is appreciable interest in only the last two format structures, and mostly as future development, so I won't devote any more space here to their discussion.

- Field alternative
- Line alternative
- Side-by-Side (Full)
- L + depth
- L + depth + graphics + graphics-depth

3D Over HDMI – Infoframe Metadata

Another aspect of the HDMI 1.4a 3D specification is the InfoFrame packets within the video stream that identify the 3D structure being used for a specific piece of content. The 3D video format is indicated using the VIC (Video Identification Code) in the Auxiliary Video Information (AVI) InfoFrame, in conjunction with the 3D_Structure field in the HDMI Vendor Specific InfoFrame. The InfoFrame data tells the display information about the picture content that the source is sending.

If you are watching 3D video content recorded with Side-by-Side 3D formatting and you then switch to content recorded with Top/Bottom structure, the sink (display) knows how to convert the video stream according to the InfoFrame data that rides with the video signal. The InfoFrame data is transmitted twice per video frame and may change when picture content changes, such as with commercials or from one show to another.

3D HDMI Display Devices

HDMI 1.4a requires that all 3D displays support 1080p24 and 720p50/60 Frame Packing, 1080i50/60 Side-by-Side (Half), and 1080p24 and 720p50/60 Top-and-Bottom 3D formats. The typical uses of these formats in different applications is likely to be:

- Blu-ray movie content: 1080p24 Frame Packing
- Gaming consoles: 720p50/60 Frame Packing
- Cable, satellite, broadcast transmissions: 1080i50/60 Side-by-Side (Half) (documentaries), 1080p24 Top-and-Bottom (movies) and 720p50/60 Top-and-Bottom (sports)

There has been much confusion lately as to the compatibility of 120 or 240 Hz 2D displays with 3D video content. While most 3D displays are capable of 120 or 240 Hz frame presentation, to be 3D compatible the display also needs to also be capable of recognizing 3D video content and converting it to a suitable form for output presentation (usually frame sequential display, controlling synchronized active shutter glasses). Unless the display is labeled as 3D-ready or 3D-capable, it probably cannot be used for 120 Hz 3D. Although it may theoretically be possible for manufacturers to provide updated firmware for some of their 2D displays to make them compatible with the 3D frame compatible formats, it doesn't appear that any manufacturers are interested in doing that.

3D HDMI Source Devices

According to the HDMI 1.4a spec, 3D video sources must support at least one mandatory 3D format. This insures that any 3D source is capable of generating a 3D video format structure that any 3D display device is capable of properly rendering. In the case that an HDMI 3D source device is capable of generating one or more of the discretionary 3D structures, it does need to check the EDID information it gets from the 3D display device, since 1.4a states, "An HDMI Source shall not send any 3D video format to a Sink (display) that does not indicate support for that format."

3D HDMI Repeaters

HDMI repeaters (AV receivers, HDMI matrix switchers, HDMI splitters, etc.) are another type of component often found in an HDMI network. The HDMI 1.4a spec says that they must transparently pass all mandatory formats. This means that they must not only pass the 3D video stream, but they must also pass the 3D InfoFrame data. Many 1.3 compliant HDMI repeaters may be able to pass the video stream, but may not recognize or pass the 3D InfoFrame data, since it wasn't part of the standard when the device was designed. Or, when the 3D display sends EDID data indicating that it is FHD3D-compliant, the repeater may not recognize the code, and just shut off the HDMI signal. In some cases, a firmware update may be available from the manufacturer to make the device compatible with at least some of the 3D formats.

3D HDMI Cables – Bandwidth Requirements
The other aspect of transmitting 3D between HDMI devices in the home has to do with the HDMI cables. With the 3D frame packing structure, more than two times as much data (pixels/sec) must be transmitted for a given frame rate, compared to 2D video. This means that a 1080p video signal at 24 frames/sec, which traditionally required a 59.4 MHz clock rate for 2D video (2,200 pixels/line*1,125 lines/frame*24 frames/sec), would require a 148.5 MHz clock rate, with a 6.75 Gbits/sec data rate, for 3D content using frame packing. This of course places a higher bandwidth requirement on HDMI cables used in the installation.

Will existing 1.3 HDMI cables handle the 6.75 Gbps FHD3D data rate signal or will you have to replace them? Category 1 (Standard) HDMI 1.3 cables are rated to handle *at least* 2.25 Gbps signals, primarily intended for handling 720p and 1080i 2D signals from cable and satellite television, digital broadcast HD, and upscaling DVD players. These cables may not be able to handle FHD3D signals. Category 2 (High Speed) HDMI 1.3 cables are rated to handle signals up to 10.2 Gbps. These should certainly be able to handle FHD3D signals.

The bottom line is that you need to understand at least some of the basics of HDMI and 3D operation to successfully combine HDMI video components into a reliable video system. And, you need to have some grasp of the basics to be able to troubleshoot systems that don’t work as expected. You also need to understand what 3D compatibility you can hope for from existing equipment so you don’t set false expectations for your clients. The information presented here is just the first step you may need to take in the world of HDMI 3D digital video networks.