“What is HD?”

The nice thing about standards is that there are so many of them!

Not all common image sizes are video standards. See table of HD formats on the next page.

Video standards

With video standards we’re really only talking about “1080” and “720” sizes: 1920 × 1080 and 1280 × 720 pixels respectively. These are pixel counts assuming square pixels on a 16:9 display. There are, in fact, four variables that we have to take into account when considering whether something is HD or not:

- Image Aspect Ratio (always 16:9 in HD);
- Image size in Pixels (and pixel aspect ratio — square vs. non-square pixels);
- Frames per Second; and
- Whether the image is Interlaced or Progressive.

Actual size — 1440 anamorphic pixels

Square vs. Anamorphic Pixels

For production formats we also need to consider whether the pixels are square or anamorphic. Anamorphic pixels are used to reduce the bandwidth of a signal by using fewer pixels, but scaling those pixels wider to fill the full Image Aspect Ratio.

For example, HDCAM shoots “1920 × 1080” HD nominally, but in fact the format only uses 1440 × 1080 pixels maximum. Each of the 1440 pixels are wider than they are tall, so that, when displayed, they fill the full space of a 1920 × 1080 square pixel display.

Displayed as 1920 square pixels

HD Formats

Type	Dimensions	Frames per second	Scanning Type
720p24	1280 × 720 (960 × 720 DVCPRO HD)	23.976	Progressive
720p25	1280 × 720 (960 × 720 DVCPRO HD)	25	Progressive
720p30	1280 × 720 (960 × 720 DVCPRO HD)	29.97	Progressive
720p50	1280 × 720 (960 × 720 DVCPRO HD)	50	Progressive
720p60	1280 × 720 (960 × 720 DVCPRO HD)	60	Progressive
1080p24	1920 × 1080 (1440 × 1080 in most formats, 1280 × 1080 DVCPRO HD)	23.976	Progressive
1080p25	1920 × 1080 (1440 × 1080 in most formats, including DVCPRO HD)	25	Progressive
1080p30	1920 × 1080 (1440 × 1080 in most formats, 1280 × 1080 DVCPRO HD in 60 Hz Countries)	29.97	Progressive
1080p50	1920 × 1080 (1440 × 1080 in most formats, 1280 × 1080 DVCPRO HD in 60 Hz Countries)	50	Progressive
1080p60	1920 × 1080	59.94	Progressive
1080i50	1920 × 1080 1920 × 1080 (1440 × 1080 in most formats, including DVCPRO HD)	25 (50 fields per second)	Interlaced
1080i60	1920 × 1080 (1440 × 1080 in most formats, 1280 × 1080 DVCPRO HD in 60 Hz Countries)	29.97 (59.94 fields per second	Interlaced

HD Frame Rates

Within those two basic frame sizes we have a variety of frame rates:

- 23.976
- 25
- 29.97
- 50
- 59.94

in both 720 and 1080 variations with interlace and progressive variants.

Frame Rate	Medium	Geographic Area
24 fps Progressive (Actual frame rate 23.976 except film)	Film, Blu-ray, Digital Distribution, HDV, XDCAM HD/EX, DVCPRO HD, AVC-Intra, HDCAM/SR	Film — Worldwide, for video formats USA, Canada, Mexico, Japan, "60 Hz countries", Digital OTA Broadcasts
25 fps Progressive	Blu-ray, Digital Distribution, HDV, XDCAM HD/EX, DVCPRO HD, AVC-Intra, HDCAM/SR	Europe, Australia, New Zealand, Asia, Africa, Latin America, "50 Hz countries", Digital OTA Broadcasts
25 fps Interlaced (aka 50i)	HDV, XDCAM HD/EX, DVCPRO HD, AVC-Intra, HDCAM/SR	Europe, Australia, New Zealand, Asia, Africa, Latin America, "50 Hz countries", Digital OTA Broadcasts
30 fps Progressive (Actual frame rate 29.97)	Blu-ray, Digital Distribution, HDV, XDCAM HD/EX, DVCPRO HD, AVC-Intra, HDCAM/SR	USA, Canada, Mexico, Japan, "60 Hz countries", Digital OTA Broadcast
30 fps Interlaced (aka 60i) (Actual frame rate 29.97, aka 59.94i — fields per sec)	Blu-ray, Digital Distribution, HDV, XDCAM HD/EX, DVCPRO HD, AVC-Intra, HDCAM/SR	USA, Canada, Mexico, Japan, "60 Hz countries", Digital OTA Broadcast
50 fps Progressive	HDV 1, DVCPRO HD @ 720P, XDCAM HD/EX @ 720P, HDCAM/SR	Europe, Australia, New Zealand, Asia, Africa, Latin America, "50 Hz countries", Digital OTA Broadcasts @ 720P
60 fps Progressive	DVCPRO HD @ 720P, XDCAM HD/EX @ 720P, HDCAM/SR	No distribution or broadcast of 1080p60, only 720p60. HDCAM/SR can shoot 1080p60

In 720 these are all progressive frames, not interlaced fields. Within 1080 there are progressive rates at 23.976, 25, 29.97 and (theoretically) 59.94 Progressive, but the only format that supports 1080 59.94 progressive is the HDCAM SR. That format — 1080p59.94 — cannot be broadcast because it is a higher data rate than the MPEG-2 profile used for ATSC broadcast or for Blu-ray disc. In 1080 there are also interlaced frame rates of 1080i25 and 1080i29.97, although they are frequently written in the field rate of 1080i50 or 1080i59.94. Don't be fooled — 1080i59.94 is the same frame rate as NTSC Television — 29.97 interlaced frames per second with 59.94 fields per second and 1080i50 is 25 interlaced frames per second, the same as PAL video.

They are the standards: there are cameras that shoot each of the formats and frame rates, and all but 1080p59.94 can be broadcast. These combinations of formats and frame rates become even more complex when adding pulldown or being able to go to solid state media, DVCPRO and DVCPRO 50, such that the Panasonic HVX200 has, and there ends up being close to 80 recording modes to choose between.

However, it becomes simpler when you realize that 23.976, 29.97 and 59.94 frame rates apply in "60 Hz Countries" (like the USA, Japan and other NTSC countries) and the 25/50 variations apply in the "50 Hz Countries" (like most of Europe, Australia and other PAL countries)

Counting Resolution

Depending on how far you are from the screen, and how large the screen is, you may not get the full benefit from even 720 HD, let alone 1080 HD. It should be obvious that 720P will meet the needs of almost all displays at common viewing distances.

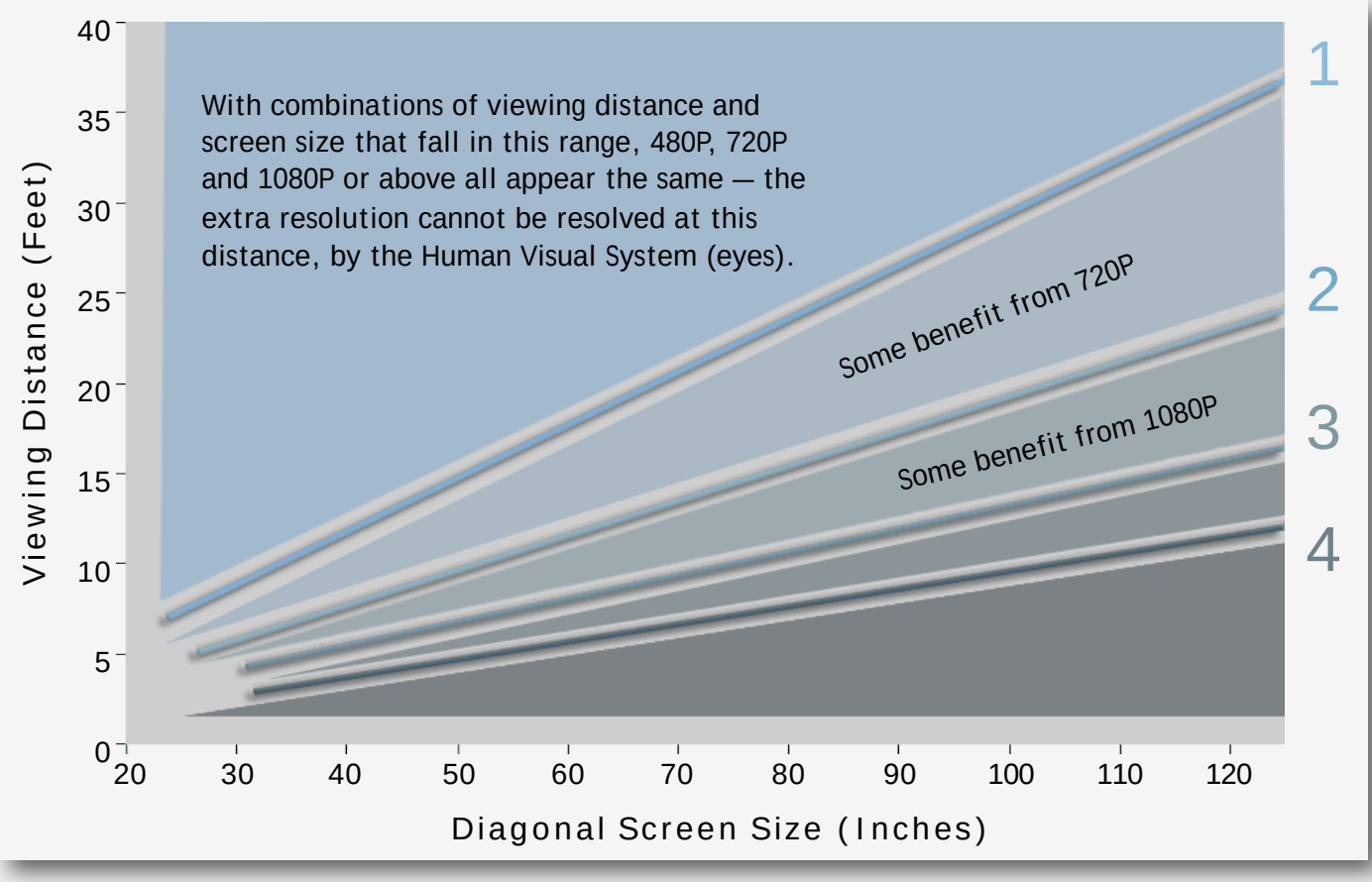
In SD most people will watch from 9 to 20 feet (3 to 6 meters) away; in HD people tend to watch from about 15 feet (4.6 meters). At that distance few can distinguish any improvement over SD-like 480P. To see the benefit of 720P you'd have to move in to 10 feet (3 meters) from the screen or increase the screen size to nearly 100 inches. A screen that size is not going to fit in my apartment!

So how much resolution do you need; how much can you benefit from? The amount of resolution that is actually required is something that geeks like to argue about in a bar, or at a conference. In practical terms the reality is that 40-50" screens won't show any benefit from a signal better than 720P, unless people sit uncomfortably close. See the Sidebar on the next page to determine how much resolution you can take advantage of in particular combinations of screen size and viewing distances.

Gizmodo recently compared the output of a Blu-ray disc, an upconverted SD DVD and an Apple TV download at 720P (of the same content) and discovered that there was not a lot of difference between the 720P download and the 1080p24 Blu-ray disc.

While 720P is definitely the sweet spot for production because it can be easily converted to 1080 when necessary and will usually deliver more useful resolution at the end viewing location than 1080i, our customers and audiences have been "sold" by the "big number" marketing of 1080. We could educate but mostly we'll simply give the customer what they ask for.

Screen Size vs. Viewing Distance
Perceivable resolution



1 The Full Benefit of 480P is visible. 480P is a step beyond NTSC, sometimes referred to as “Extended Definition”.

2 The Full Benefit of 720P is visible.

3 The Full Benefit of 1080P is visible. The full benefit of 1080i will be close to 720P

4 The Full Benefit of a proposed new standard, 1440P is visible. There are no readily available sources of 1440 vertical line televisions or projectors.

Draw a line up from your screen size and across from the viewing distance. The intersection point will indicate how much resolution you will be able to perceive from that viewing distance. For example, a 42” screen at 10’ (approximately 3× screen height), the typical viewing distance for HD, you would get some benefit from 720P but would not be able to see the full quality of 720P. To get the full benefit of 720P you’d have to move the seat closer, to about 8’ from the screen. For the full benefit of 1080P, you’d need to be an uncomfortably close 5’ from the screen.

If you examine the chart carefully, taking into note typical screen sizes and viewing distances, you’ll see that few situation can take advantage of much more than 720P quality.

It is trivial to take a 720P (either 23.976P, 29.97P or 59.95P master) and provide it to someone as 1080i60 (remembering that you cannot give it to them as 1080p60). It doesn't matter so much what we produce because we can give them whatever output format they want. The average consumer will never, ever, see the difference in quality, between 720P scaled up to 1080i and something that was 1080i throughout the process. In fact, the 720P source will probably be better because it won't have been as compromised during production.

Even where the viewer is in a home theater and could tell the difference if they could compare the two versions (720 and 1080) in an A-B comparison, most people will not tell the difference when up close, and three paces back to a normal viewing distance the difference would be imperceptible.

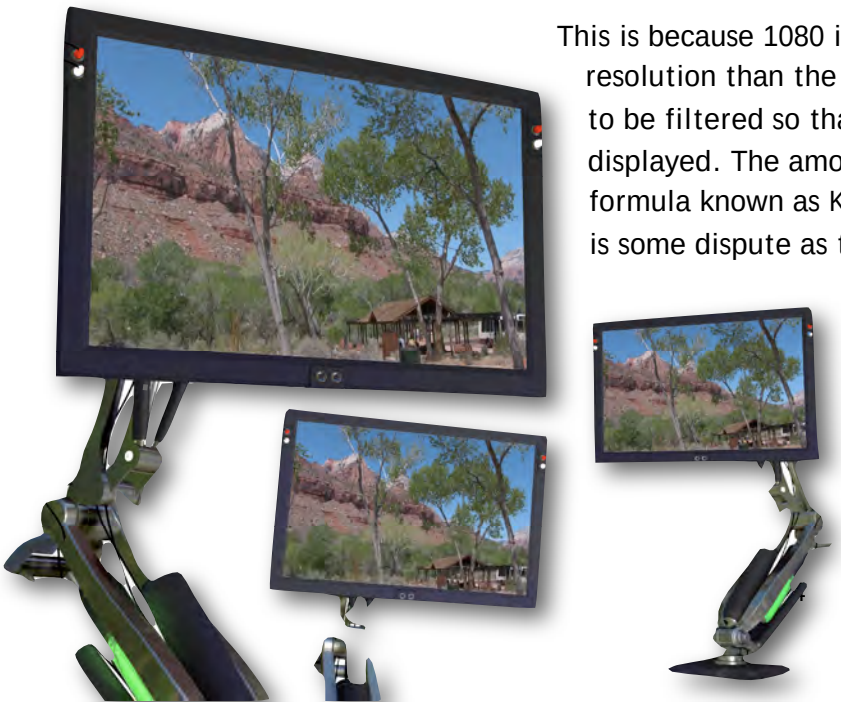
Main conclusion from the EBU Report

"The demonstration suggests that a progressive format for emission provides the best image quality / bitrate compromise with MPEG-4 AVC compression. EBU Members have already been advised in EBU Recommendation R-112 that the 720p/50 emission format is currently the best option. The demonstration has underlined this statement.

Once interlacing is applied to an image format, vertical-temporal information is lost that can never be recreated. The interlaced "footprint" causes an unnecessary burden in the digital broadcast chain, particularly since modern content-adaptive compression systems such as MPEG-4 AVC perform better with progressive signal sources than with interlaced signals. Furthermore, de-interlacing chips are not needed in flat-panel matrix displays, thus avoiding a further point of image-quality impairment and video-audio delay."

EBU Testing

The European Broadcasting Union (EBU) at IBC has proved this over the last two years (See Sidebar above). While the 1080i master looks visibly better compared to 720P on the studio monitors, when the evaluation is done at the end of the delivery system — broadcast or Blu-ray — then the 720P material delivers more on-screen quality than 1080i under the same delivery settings. 720P delivers more real useful resolution, or sharpness, than 1080 interlaced source through a 1080i delivery channel. It's counterintuitive but that is the reality.



This is because 1080 interlaced material has lower vertical resolution than the numbers would imply. Interlaced images need to be filtered so that single-line-high detail doesn't flicker when displayed. The amount of filtering required is derived from a formula known as Kell Factor or perhaps, Interlace Factor (there is some dispute as to whether-or-not they're describing the same thing). See Sidebar on the next page.

The Kell/Interlace Factor Effect on Resolution

For interlaced video the Factor is 0.7, which means that the equivalent interlaced resolution is only 0.7 (70%) of the progressive resolution. By this measure the 1080 interlaced lines deliver the equivalent of 756 progressive lines. That's barely more vertical resolution than 720, which has 720 progressive lines in the vertical dimension.

As we'll see later, even the 1920 dimension is compromised in most affordable cameras, with 1440 pixels across being the most common real pixel dimension for "1080" cameras. (See the Square vs. Anamorphic examples earlier.)

Has anyone used a Panasonic HVX 200? That's the one that shoots to P2 media. That camera originally had sensors that are only 960 × 540 pixels. That's fewer pixels than 720p!

And yet, by offsetting one of the chips slightly by half a pixel (see the Pixel Shift illustration later), they synthesize a "1080i59.94" signal. (In DVCPRO HD that's an image size of 1280 × 1080 in 60 Hz countries, 1440 × 1080 in 50 Hz countries.) Despite have the lowest pixel count on its chips of any of the "affordable HD cameras" the HVX 200 produces an excellent image that thousands have been happy with.

The Kell or Interlace Factor

"When interlaced scanning [drawing all the odd lines then all the even lines] is used, as in all the conventional [video] systems, the 70 percent figure applies only when the image is fully stationary and the line of sight from the viewer does not move vertically by even a small amount. In practice, these conditions are seldom met, so an additional loss of resolution, called the interlace factor, occurs under typical viewing conditions.

This additional loss depends on may aspects of the subject matter and viewer attention, so there is a wide range of opinion on its extent. Under favorable conditions, the additional loss reduces the effective value of vertical resolution to not more than 50%, that is, no more than half the scanning lines display the vertical detail of an interlaced image. Under unfavorable conditions, a larger loss can occur.

The effective loss also increases with image brightness, as the scanning beam becomes ... [fatter]."

From K. Blair Benson and Donald G. Fink, "HDTV: Advanced Television for the 1990's", 1991, McGraw Hill, NY, bracketed words added by Allan W. Jayne in his article on Kell and Interlace Factor.

Marketing and perception is very important. The takeaway from this discussion is that you do not have to shoot in the format you plan to deliver, if that's not what works best for your equipment and workflows.

You can always take a 720P signal and scale it up to 1080p24 or convert to 1080i59.94. The conversion is trivial with the correct equipment, and the quality is transparent to the conversion. There are many service bureaus that have that capability in the major production markets, and software solutions otherwise. With HD we can scale up, and down, without compromise. It really does depend on what people are expecting: that's absolutely true. Obviously if they expect something of the nature of HDCAM you'll have to work with HDCAM to give them that. Or you may not need to shoot HDCAM. Proving the point that resolution, alone, is not all that matters.