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7 Primaries for HD content

In last month's article I discussed the demise of the CRT as the definitive display device for approving colour content of HD programming. The inability of content creators to obtain CRT reference displays causes an immediate need for a replacement. However, even in the era when CRT reference displays were viable, there was a latent issue that no one talked about, and it's that issue that I'd like to raise this month: Worldwide standards for HD specify BT.709 primaries.

If you're a consumer video expert, perhaps a home theatre calibrator, you say, well, *of course, that's obvious!* But let's investigate.

ITU-R Rec. BT.709 is the main international standard for HD content. *R'G'B'* values are supposed to be displayed according to a particular set of primary chromaticities specified in the document. The Recommendation was adopted in 1990. (It was called CCIR Rec. 709 at the time). In the years following, various national and continental standards followed suit. For example, SMPTE 274M, the main studio production standard in North America, states:

> "Equipment should be designed in accordance with the colorimetric analysis … defined in this section. This corresponds to ITU-R BT.709."

Comparable provisions are found in ATSC, DVB, and EBU standards.

In 1993, the computer industry enthusiastically adopted the BT.709 primaries as one aspect of the sRGB standard. The sRGB standard is now ubiquitous for desktop computing, not just for stills (such as Exif JPEGs), but for video: sRGB video encoding is implicit in new video distribution channels such as YouTube, Skype, the Apple iTunes Store, Hulu.com, Netflix, and so on.

Sony's BVM-D32E1W CRT was the "gold standard" studio reference display. It was available with SMPTE or EBU phosphors – but was never offered with BT.709 phosphors!

However, HD content creators hold a dark secret: Following international agreement on BT.709 in 1990, content creators in 60 Hz countries never switched from the SMPTE primaries of 480*i* SD to the BT.709 primaries, and content creators in 50 Hz countries never switched from the EBU primaries of 576*i* SD to the BT.709 primaries. HD content is generally *not* approved on BT.709 displays! SMPTE "C" (RP 145) primaries remain entrenched for 60 Hz HD in North America, Japan, and much of Asia; EBU primaries remain entrenched for 50 Hz HD in Europe and other parts of the world.

BT.709 supposedly exists for international exchange; however, international HD program exchange in practice does not use BT.709. We find ourselves in the ironic situation that studio and broadcast HDTV does *not* use the "HDTV" (BT.709) primaries, but the computer industry has embraced them to the virtual exclusion of everything else! (Displays having Adobe RGB 1998 primaries are deployed in limited numbers for applications in high-end graphics arts.)

SD and HD luma coefficients differ, necessitating a transform of $Y'C_BC_R$ upon conversion between SD and HD. Within any geographical region the underlying *R'G'B'* are identical, though, so the discrepancy in luma coefficients has absolutely no effect on colour gamut or "colour space." By the way, there's no such thing as "BT.601 colour space." BT.601 is primary-agnostic. It is implicit that 480*i* content has SMPTE primaries and 576*i* content has EBU primaries.

High-end HD production and distribution standards conversion equipment (such as from Snell & Wilcox and Teranex) can be configured to perform colour primary transforms among SMPTE, EBU, and BT.709 primaries at the time that programme material is subject to standards conversion (say from 60 Hz to 50 Hz). However, if such a conversion is done, gamut clipping and gamut mapping issues are liable to arise. In my view, it is best to leave the *R'G'B'* alone, and live with some small systematic colour errors (which are unlikely to be visible without comparison to the original) rather than risk gamut clipping (which is likely to be visible even without access to the original).

At the consumers' premises, 60 Hz content has almost certainly been mastered with SMPTE primaries. If you're a home theatre calibrator, you may be tempted to calibrate your display primaries to the SMPTE spec rather than BT.709. In my view that would be a mistake, for the reason that I mentioned a moment ago in connection with colour primary transforms in production: The risk of artifacts from colour clipping outweighs any advantage in colour accuracy – and in any event, when transmitted through an ATSC or DVB channel, the content effectively declares itself to be BT.709, so that's how you should display it.

Studio display manufactures will face increasing difficulty in sustaining a pair of legacy chromaticity sets (SMPTE and EBU) for high end HD content, especially when the discrepancy with BT.709 confers no functional benefit. In the face of increasingly global distribution of television programmes, and with a single worldwide standard for desktop computing used in emergent video distribution technologies, it will be increasingly difficult for content creators, aggregators, and broadcasters to justify different primary chromaticities for 50 Hz and 60 Hz regions. The next 1 to 4 years will see replacement of CRTs across virtually the entire installed base of studio reference displays. Deployment of FPD studio reference displays (not "monitors"; see Issue 5) provides an opportunity for broadcasters throughout the world to migrate to BT.709 primaries. In my view, that's the only sensible way forward is BT.709. If you're a home theatre enthusiast, calibrating to BT.709 prepares you for this eventuality.

Wide-gamut television receivers are now commercially available that warp perfectly reasonable BT.709 colours into regions of colourspace that the content creators never intended: I call it *wild gamut*. Faithful presentation cannot be achieved with such processing. HDMI 1.4 and xvYCC/x.v.Color are implicated. The development of legitimate wide gamut will be the subject of a future issue. Meanwhile, I welcome your comments! ■