Introduction
For many, the inclusion of "Gamut Error" indications on video test equipment may seem like the ideal solution to the problem of assessing content for legality and with many units now providing a log output some users are now relying on the log files to pass and fail content - but should they?

Why check gamut at all?
The original reason for checking gamut was to protect analogue transmissions and transmitters. The original gamut defined the range of colours that could be guaranteed not to over modulate the composite transmitters and so avoid damage to the transmitters and the distortion that could lead to spectral leakage resulting in one channel interfering with another. For both of these issues transient excursions are of little consequence but the magnitude of any non-transient excursion is important in determining the likely effect.

How does RGB legalisation fit into this?
This set of colours or 'gamut' was defined in the composite domain as this was the domain it was trying to control but as legalisation in the composite domain is computationally very intensive many users settled for RGB domain legalisation which was more widely and cheaply available. RGB legalisation relies on the RGB domain being a subset of the composite domain so that any signal which is RGB legal is inherently also composite legal (the converse if of course not the case). In light of the move to digital television and the widespread adoption of RGB legalisation the EBU released a technical recommendation for legalisation based primarily on the RGB legalisation model but with separate restrictions on RGB and luminance excursions. This is known as EBU R013-2000 and has been widely adopted by broadcasters.

What is the issue with gamut alarms?
Too blunt a tool
The essential operation of a gamut alarm is to convert every pixel in the picture into the target colour space (RGB for RGB legalisation) and then count the number of pixels which lie outside of the allowed gamut. For many, one pixel in a whole frame which is illegal by about 0.05% (half of one bit) is indicated as just as illegal as every pixel in the frame being as illegal as possible. Clearly one is going to cause a problem and the other is not. Pixel based "gamut indicates" go someway to providing more information to the user but you still cannot tell the difference between really illegal pixels and those that are only just illegal.

Are legalisers the solution?
Legaliser are the solution to the real problems associated with out of gamut colours but they wont necessarily guarantee that you never see a gamut warning. RGB or Composite legaliser operate in different colour spaces to the YCbCr colour space of SDI video so before the signal can be legalised it needs to be colour-space converted into the appropriate colour-space and then converted back again afterwards. All such conversions are inherently imperfect due to the finite accuracy of representing the colour-space conversion coefficients. To make matters worse SDI is sub-sampled to a 4:2:2 colour representation and every other pixel needs to be mathematically interpolated from its neighbours again with finite accuracy. The net result of all this is that every piece of equipment implements a slightly different colour-space conversion, due to these rounding errors, which can result in one piece of equipment to consider a particular pixel just legal while another considers it just illegal. It also impossible to produce a perfect inverse colour-space conversion so even after a signal has been legalised once the same legaliser may indicate some pixels as being illegal when reprocessing the signal. The difference now is that where it might have been 10% illegal in the first pass it is not only 0.05% illegal.
In addition to these legitimate mathematical limitations on assessing the legality of a signal we have also identified "artefacts" in the algorithms used by some test equipment to assess legality, especially at the picture edges, which can cause them to falsely indicate some signals as having gamut errors when they quite clearly and demonstrably did not.

So what should we do?
If you want to partially automate assessing signals for gamut then use the logged gamut warnings to direct you to those areas that need further investigation but always review those areas with a view to how severely illegal they are by using a waveform monitor, in which case you need to watch out for apparent overshoots caused by "ringing" in the analogue circuitry or display smoothing, or using a piece of equipment which gives you more
qualitative view of the gamut legality of a signal. This can be through the use of a product like the eyeheight LegalEyes which features a unique 3D gamut indicator on the monitoring output which not only conveys which pixels are illegal but how severely illegal they are and produces a graphical log against time-code of how many pixels are illegal and how many of them are severely illegal based on a user specified threshold.

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