



The NTSC Color Triangle Is Obsolete, But No One Seems to Know

by Seyno Sluyterman

The NTSC (National Television System Committee) color triangle is frequently used as a reference for the color gamut in papers on the subject. However, few in the display industry seem to be aware that the NTSC color triangle is not appropriate for existing TV systems. This misuse of the NTSC triangle is undesirable both from a tutorial point of view as well as from a display design point of view.

The NTSC color triangle was defined at the beginning of color television in 1953. However, because the phosphors that were needed were not lumen efficient, it turned out to be impractical. Gradually, the color triangle changed in order to allow more-efficient phosphors. So, when the European color TV systems were defined in the 1960s, regulators looked at the experience in the U.S. and more or less defined what had become the de-facto American standard. This became the EBU (European Broadcasting Union) color triangle.

Although the NTSC color triangle was never redefined, even in countries where the NTSC television transmission system is used, the actual color triangle is very similar or equal to the EBU color triangle. At a later stage, the situation was formalized for high-definition (HD) TV. The HDTV color triangle that is agreed upon worldwide is the Rec. 709 triangle, which is also very similar to the EBU color triangle. Table 1 and Fig. 1 give the color points and spectrum locus in the CIE (International Commission on Illumination) 1931 xy chromaticity diagram; Table 2 and Fig. 2 give the color points and spectrum locus in the (more color uniform) CIE 1976 $u'v'$ chromaticity diagram.

Table 1: The coordinates of the three color triangles in the CIE 1931 xy chromaticity diagram

	xR	xG	xB	yR	yG	yB
NTSC	0.67	0.21	0.14	0.33	0.71	0.08
EBU	0.64	0.29	0.15	0.33	0.60	0.06
Rec. 709	0.64	0.30	0.15	0.33	0.60	0.06

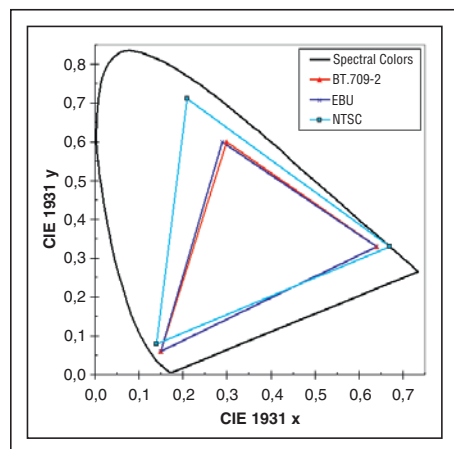


Fig. 1: The color triangles in the 1931 (xy) chromaticity diagram.

Table 2: The coordinates of the three color triangles in the CIE 1976 $u'v'$ chromaticity diagram

	$u'R$	$u'G$	$u'B$	$v'R$	$v'G$	$v'B$
NTSC	0.477	0.078	0.152	0.529	0.576	0.196
EBU	0.451	0.121	0.175	0.523	0.561	0.158
Rec. 709	0.451	0.125	0.175	0.523	0.563	0.158

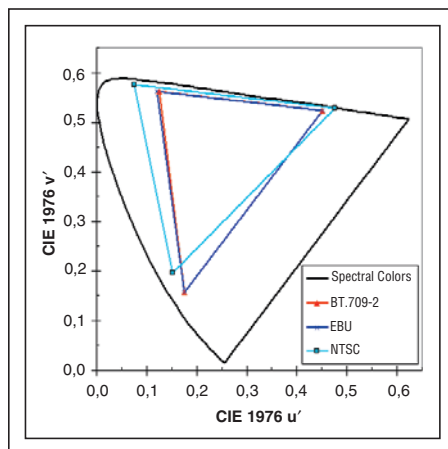


Fig. 2: The color triangles in the CIE 1976 ($u'v'$) uniform chromaticity-scale diagram.

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So, there are two problems with using the obsolete NTSC triangle as a reference. First, it puts anyone that is reading (SID) papers as a source of learning material on the wrong foot. I questioned a number of participants during the EuroDisplay 2005 and IDW '05 conferences and discovered that most of them were convinced that the NTSC triangle was actually being used. Only a few said they knew that it is not, but they used the NTSC triangle just because the others did. Second, some may put a great deal of effort in designing a display for the NTSC color triangle to discover that, in actual TV applications, the colors had grown worse than they were before!

So what are the alternatives? I recommend the following steps:

1. Use the NTSC triangle only for placing color gamut data into a historical context.
2. Adopt the Rec. 709 triangle and design displays that cover this triangle entirely.
3. If one wants to quantify the size of the gamut of the display, use triangle surfaces in the CIE 1976 $u'v'$ uniform chromaticity-scale diagram, rather than the surfaces of the triangle in the CIE xy chromaticity diagram (see note).
4. When a larger gamut than what Rec. 709 allows is needed, then be aware that one is entering the field of color-gamut extension. This means that such displays have to be combined with color-mapping algorithms and/or a wide-gamut signal source. Then, it is worthwhile to investigate first where the extra colors really are before redesigning the display.

Note on the Chromaticity Diagrams

After the CIE 1931 xy color system was defined, D. L. MacAdam investigated for 25 different points in the xy diagram, the size of the areas around these points that were seen as having the same color. He noticed that these areas were generally elliptical, and these areas became known as the MacAdam ellipses. These ellipses are, in the xy chromaticity diagram, also very different in size; the surface of the largest ellipse is 74 times larger than the surface of the smallest ellipse. To overcome the problem of the change in surface and shape, several systems have been proposed. An attractive system to use is the 1976 $u'v'$ uniform chromaticity-scale diagram (not to be confused with the 1960 uv uniform chromaticity-scale diagram or 1976 $L^*u^*v^*$

system) because transformation is simple and can also be inverted, straight lines in the xy diagram remain straight lines in the $u'v'$ diagram, and uniformity of the surfaces of the MacAdam ellipses is significantly better!

For these reasons, the surface of a triangle in the $u'v'$ uniform chromaticity-scale diagram are much more representative for the amount of different colors that can be reproduced than the surface of a triangle in the xy chromaticity diagram.

The transformations from xy to $u'v'$ are

$$u' = \frac{4x}{3-2x+12y} \quad v' = \frac{9y}{3-2x+12y}$$

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