

# Report From the Ad Hoc Group on Video-to-Film Transfer Characteristics

By Gavin Schutz

This Ad Hoc Group (AHG) was created by the Working Group on High Definition Electronic Production and charged with determining the conditions for producing film images from a video source that would match those from a film source. While the experimental work of the AHG has utilized an electron beam recording (EBR) transfer system, the fundamental concepts should apply to other video-to-film transfer technologies.

The approach taken was to develop a mathematical model of the tape-to-film transfer process to determine the necessary signal-processing requirements for an SMPTE 240M colorimetry video source to be transferred to motion-picture film negative and produce colorimetry that would match an original film camera negative. In practice, this match will never be perfect, so the AHG has performed actual transfer tests to verify integrity of the mathematical model and demonstrate with real film samples the degree of match that can be achieved.

A block diagram of the model is shown in Fig. 1. This diagram shows the SMPTE 240M signal source and the five steps needed in the transfer process. The signal processing is divided into two sections. The first section should be common to all transfer processes, and a second section will be specific to each transfer process.

The key processing steps are:

A. Linearization of the 240M signal followed by the linear matrix. This matrix can be thought of as transforming the 240M ideal camera analysis into the film negative spectral analysis. It is sort of a backwards studio camera analysis, going from the defined ideal analysis back to the "raw camera analysis." In this case the raw

camera analysis is replaced by a film spectral sensitivity. The derivation of this matrix employs the same methodology and is essentially the same as deriving a linear matrix when designing studio video television cameras.

B. Developing the model to take into account characteristics of the particular tape-to-film transfer system under test. This step involves characterization of proprietary technology and modelling of the log signal processing as well as "gamma" precorrection for the transfer process.

Several simulations using this model have been run to illustrate the importance of the linearization of the 240M signal followed by the linear matrix as listed under (A) above. For our simulations and practical tests we were able to arrange for the color film stock used in the EBR system output to be the same stock used for the comparison of normal film camera negative. This eliminates the need for log masking modelling in the system specific part of the model and greatly simplifies the simulations.

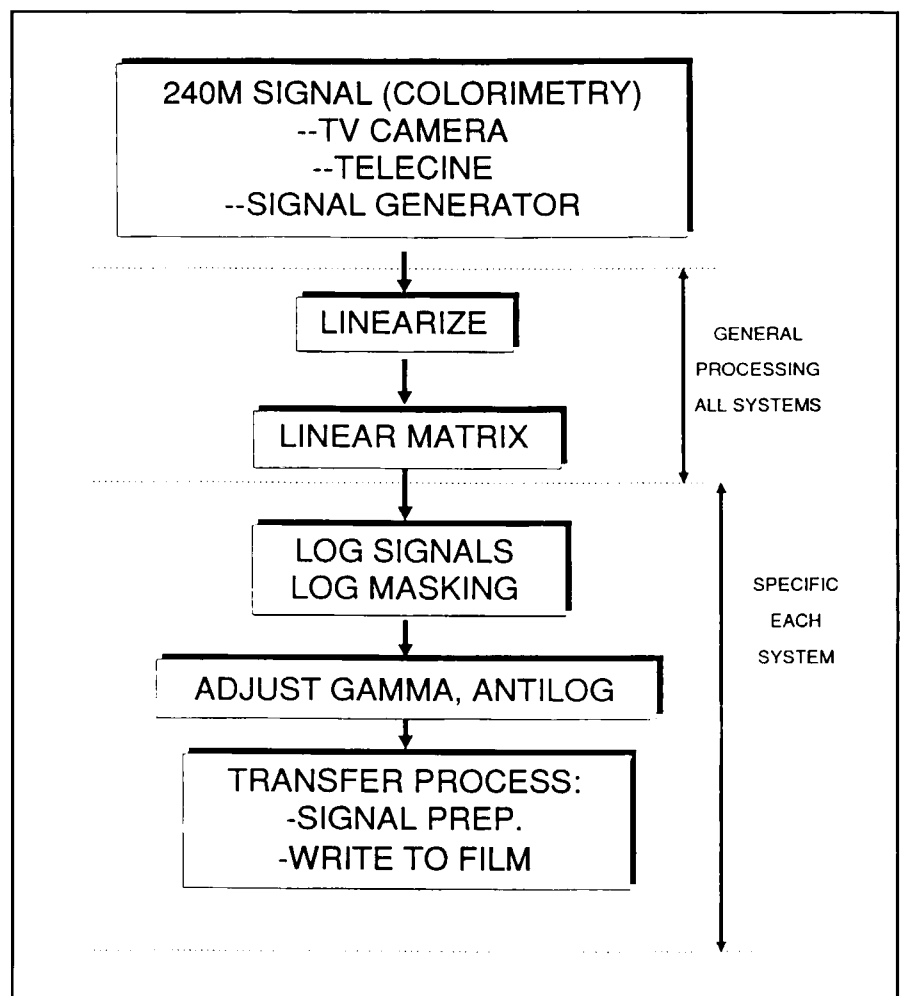


Figure 1. Video-to-film transfer process.

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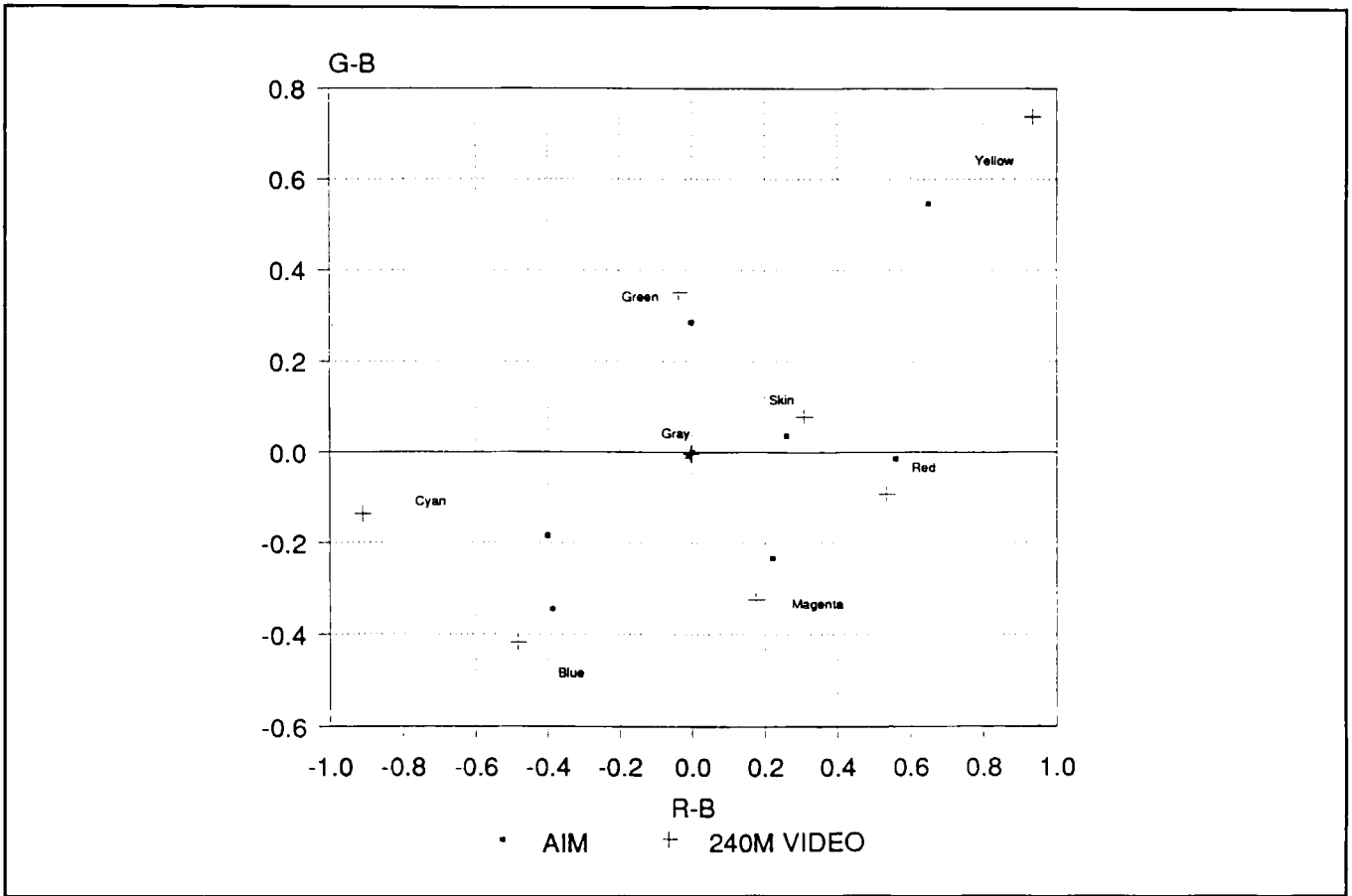


Figure 2. Theoretical video-film model; no matrix on 240M video signal.

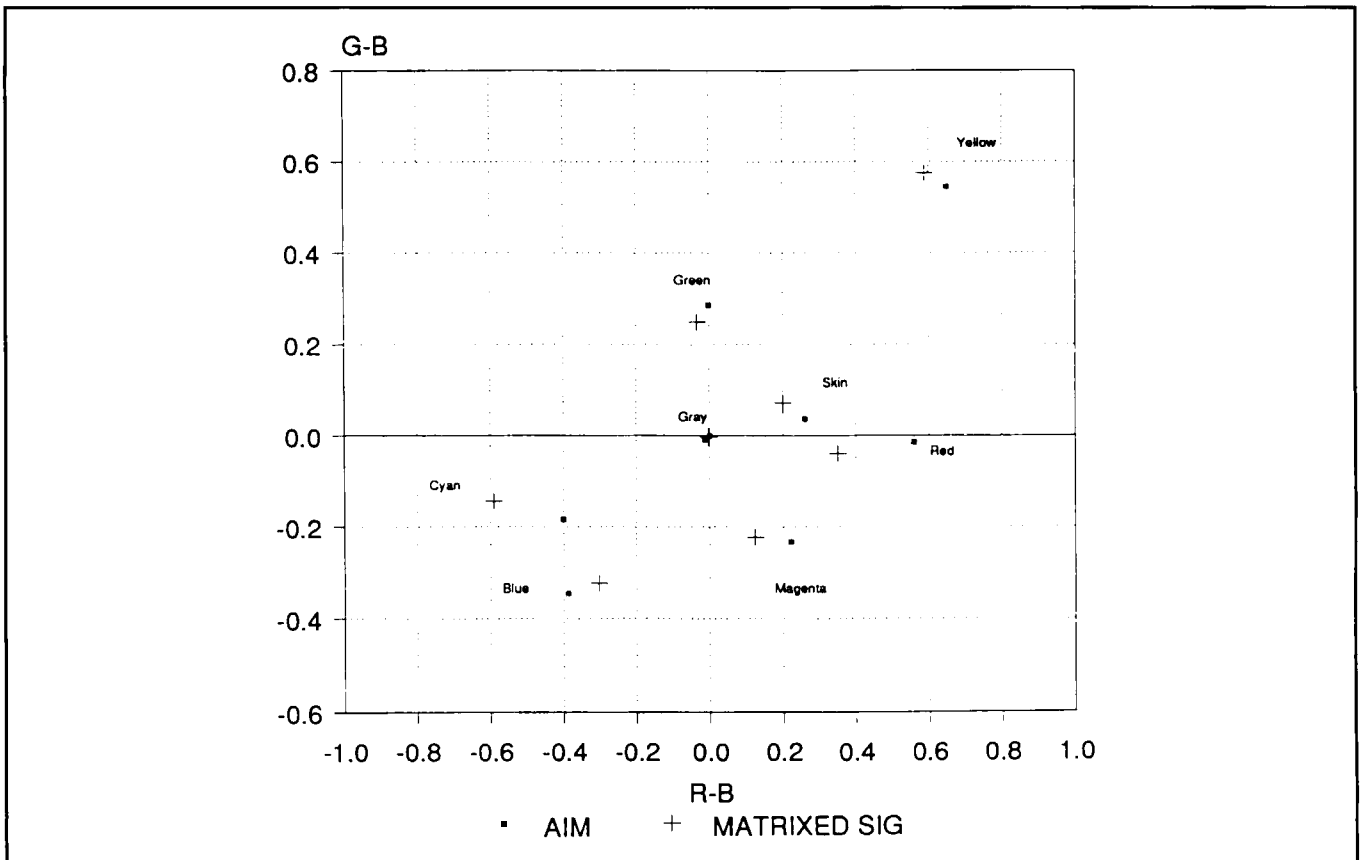


Figure 3. Theoretical video-film model; linear matrix on gamma-corrected 240M video.

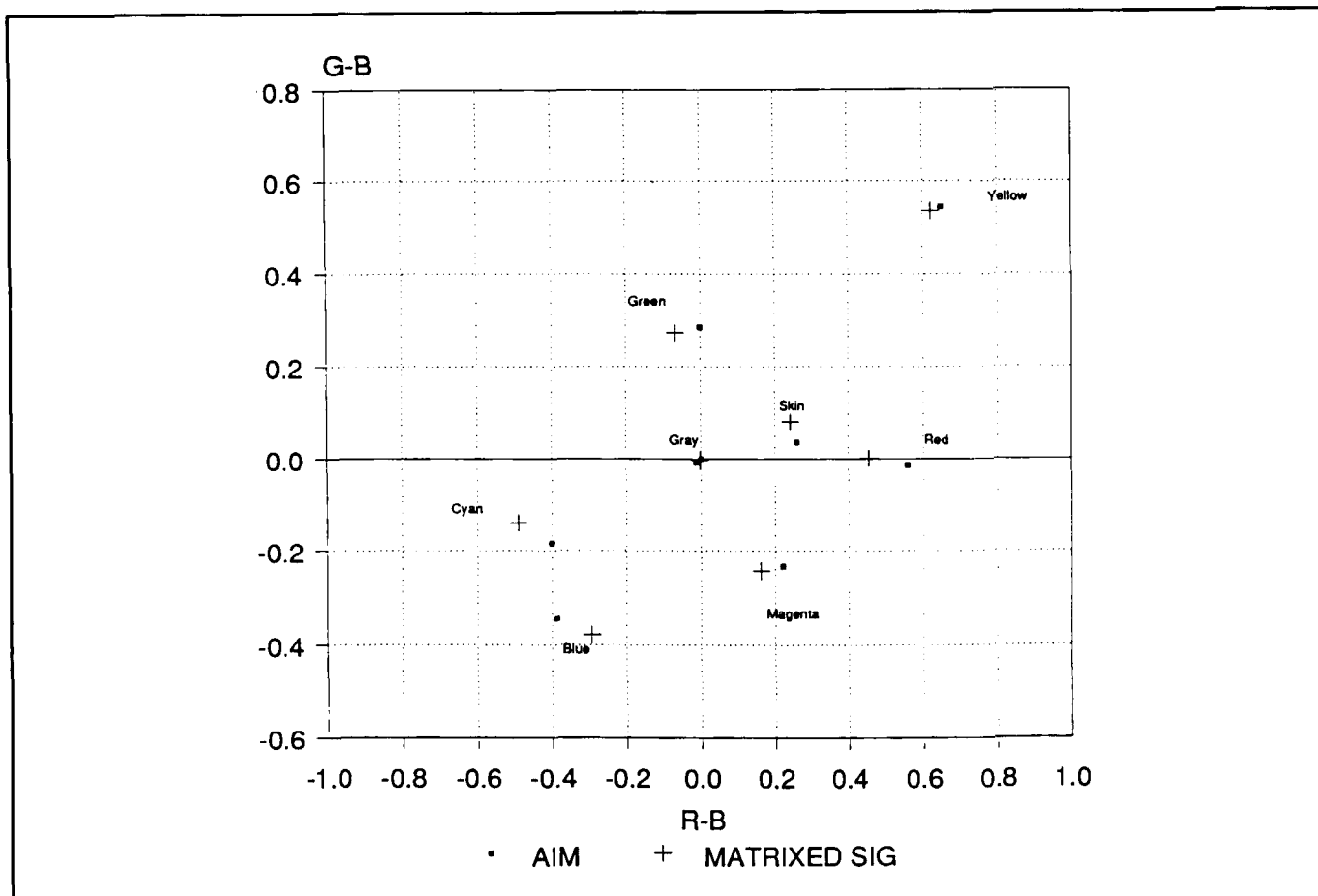


Figure 4. Theoretical video-film model; linear matrix on linearized 240M video.

Figure 2 shows a computer simulation in which no linear matrix is used. Eight colors from a Macbeth Color Checker are shown with the solid squares indicating the film camera negative reproductions (the aim) and the + symbols indicating the EBR transfer reproductions. The data plotted are status  $M$  densities of the film images with Green-Blue plotted against Red-Blue. This results in a diagram that can be interpreted in much the same way as a CIE diagram. Gray plots in the middle (at 0.0); the further a color plots radially away from gray, the more saturated it is.

Examining this plot reveals that the computed EBR transfer in general has much higher saturation than the film aim. We note that this result is in qualitative agreement with all the experimental HDTV-to-film transfers produced by the SMPTE Working Group on High Definition Electronic Production in its practical tests.

A simulation in which a linear matrix is applied directly to the 240M gamma-corrected video is shown in Fig. 3. In this simulation we attempt to

avoid the linearization step and derive an optimized matrix for the nonlinear video. The matrix used here was generated by simple linear regression of the 240M nonlinear signals with the known aim signals derived from real camera negative film.

As shown in Fig. 3, the differences between real film and the video-to-film transfer are reduced, but are still large. The largest difference is about 0.2 density units on the negative, which will translate to perhaps 0.5 or 0.6 on a print. There is little doubt that this difference would be easily noticed by a skilled observer.

A simulation including both of the key processing steps is shown in Fig. 4. Here the 240M signal is first linearized and a linear matrix, optimized for use on the linear signals, is applied. The color density differences between the real film camera negative and the video-to-film transfer are significantly smaller than those on the first two plots.

The differences shown in Fig. 4 may represent the minimum difference that can be achieved using just a linear

matrix. This is because the film sensitivities and the 240M ideal analysis are not linearly related. A matrix including higher-order terms would certainly further reduce these differences.

The practical transfer tests have also used the Macbeth Color Checker as the color test pattern. The signals to be transferred to film are generated off-line in a computer and then used to create an electrical test pattern using the Magni 2021 Test Pattern Generator. This approach has enabled the AHG to conduct five tests without the need for hardware modifications to the transfer process. The results of these tests have served to outline several problem areas in the transfer process that must be further defined.

It seems unlikely that these problem areas can be addressed quickly, so further hardware tests must be postponed. However, the theoretical part of the AHG's work is of immediate value and we offer it as a final report.