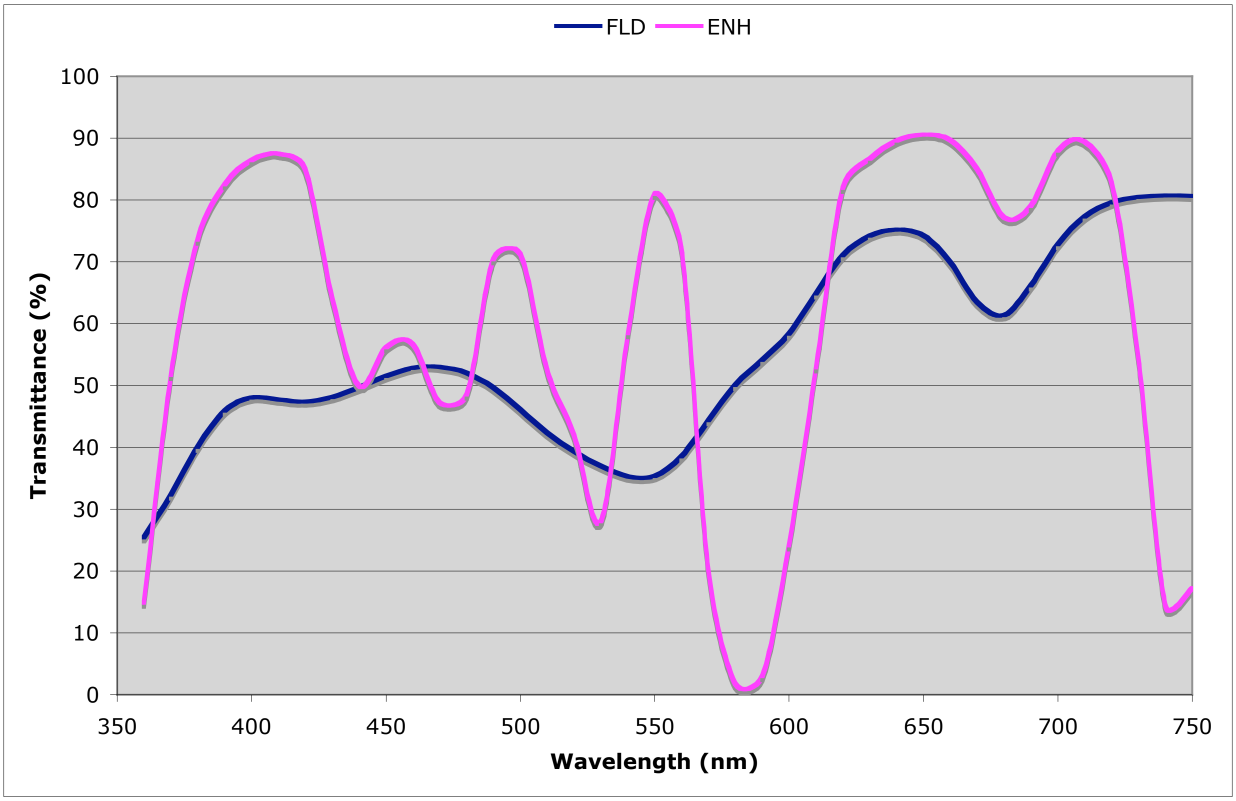
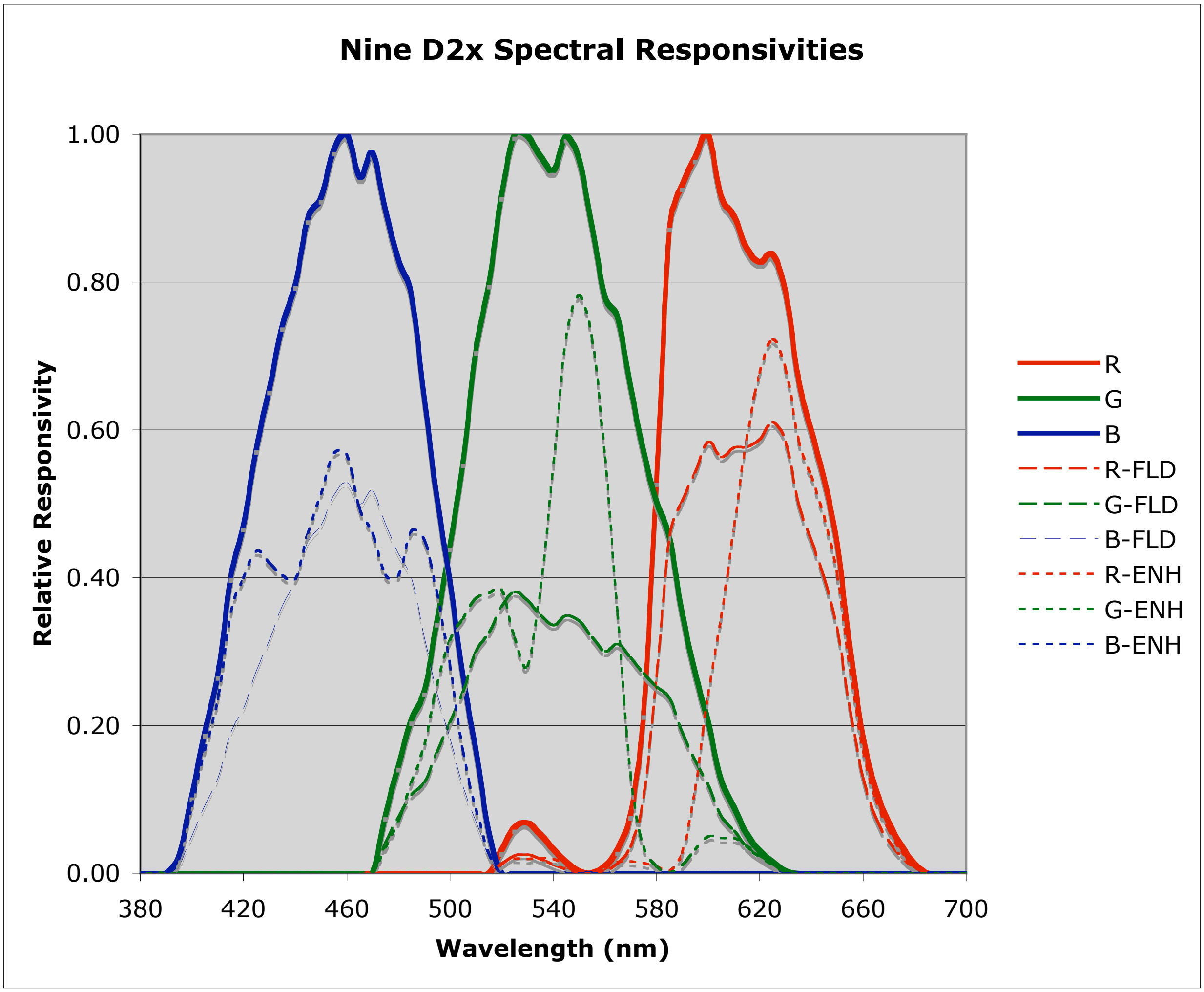
Nikon D2x Simple Spectral Model for HDR Images

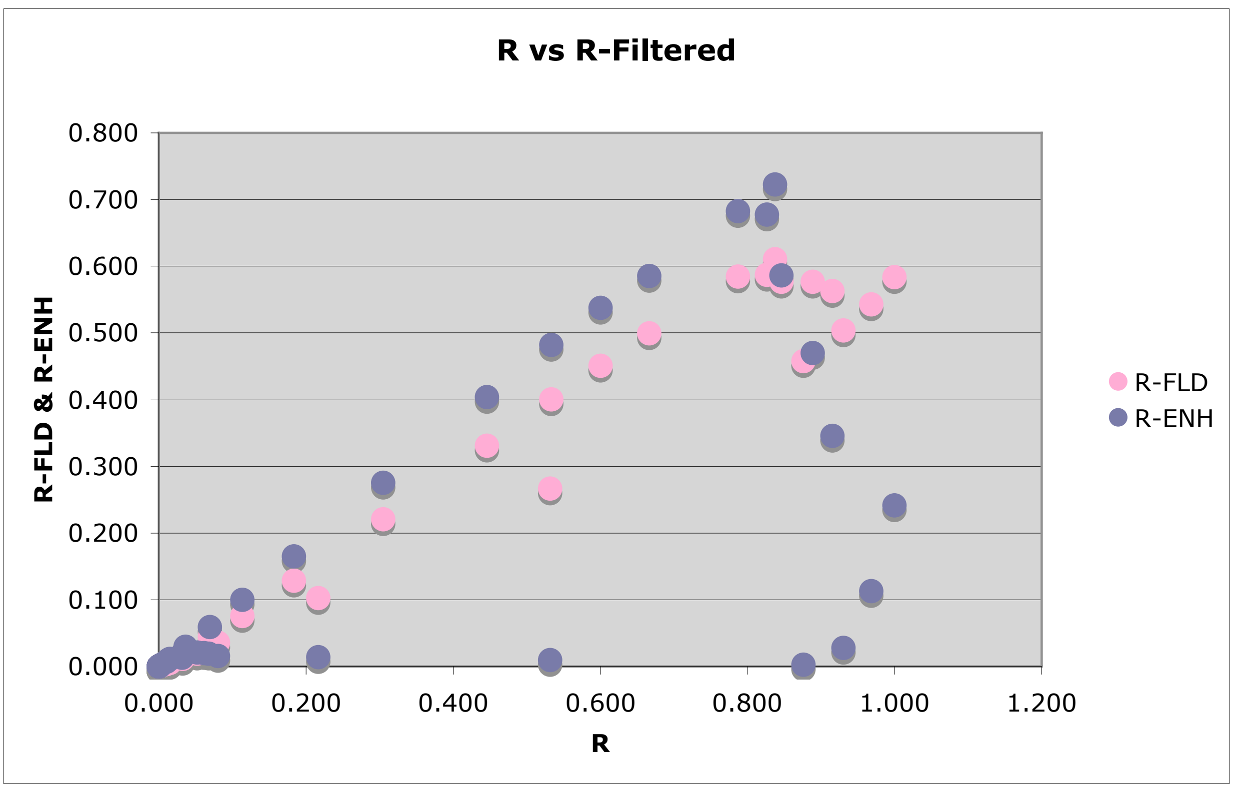
The D2x was used for simple spectral imaging by capturing 3 sets of images (Clear, Tiffen Fluorescent Compensating Filter, FLD, and Tiffen Enhancing Filter, ENH). The FLD filter is designed to compensate for the green cast in fluorescent lighting and is a light magenta filter. It serves to shift the red and blue responses toward longer wavelengths. The ENH filter is a didymium filter designed to enhance color. It serves to push the green and red responses apart spectrally. Plots follow.

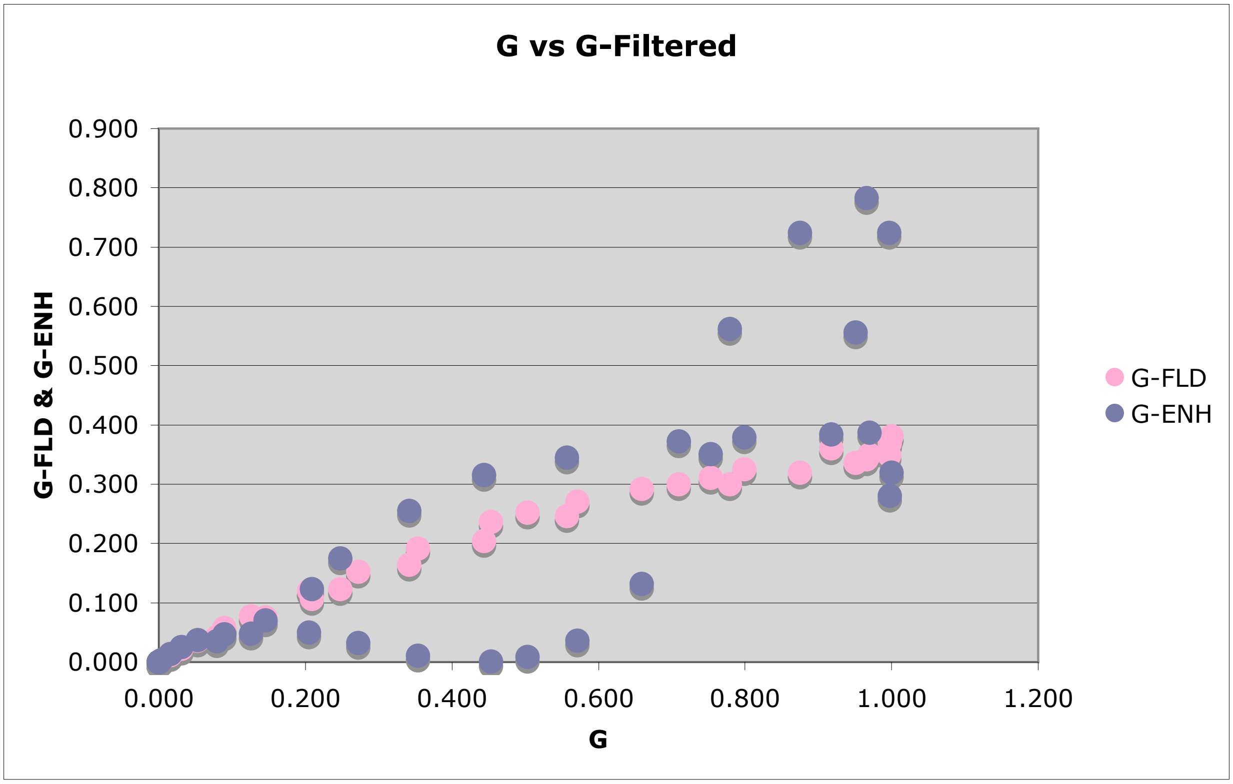


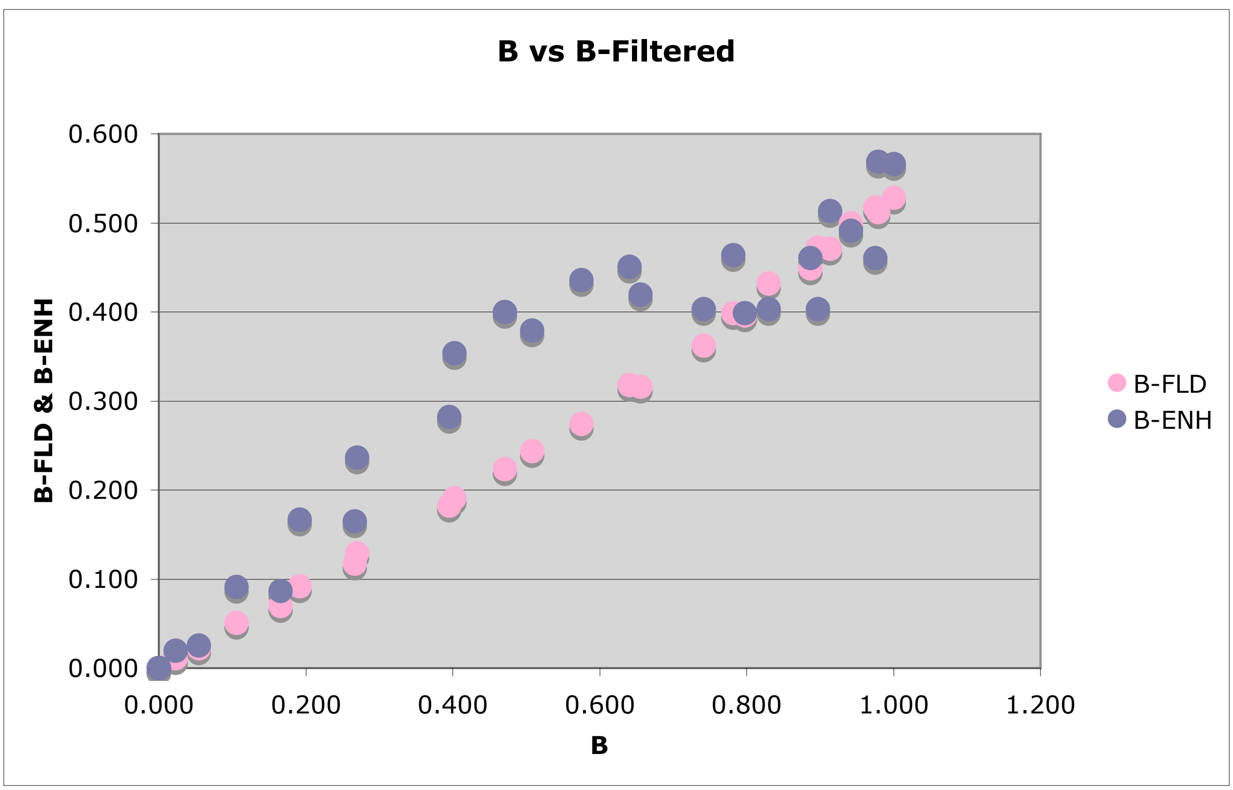


A correlation matrix for the 9 spectral responsivities was computed and is given below. Only the B and B-FLD are too correlated to not be of practical utility (red text). Thus the system is effectively 8-channel with B-FLD being redundant (but perhaps useful for noise reduction). Other pairs with statistically significant correlation are the each clear channel with its filtered versions and the filtered versions with each other (orange text). However, the plots below show that there is meaningful differences in the spectral data obtained and the significant correlation is largely from the zero-response wavelengths.

	R	***G***	***B***	***R-FLD***	***G-FLD***	***B-FLD***	***R-ENH***	***G-ENH***	***B-ENH***
R	1.00								
G	-0.08	1.00							
B	-0.50	-0.31	1.00						
R-FLD	0.99	-0.15	-0.48	1.00					
G-FLD	0.03	0.98	-0.31	-0.05	1.00				
B-FLD	-0.49	-0.32	1.00	-0.47	-0.31	1.00			
R-ENH	0.76	-0.32	-0.40	0.85	-0.28	-0.39	1.00		
G-ENH	-0.29	0.84	0.51	-0.30	0.78	-0.19	-0.26	1.00	
B-ENH	-0.50	-0.33	0.96	-0.47	-0.32	0.95	-0.39	-0.19	1.00





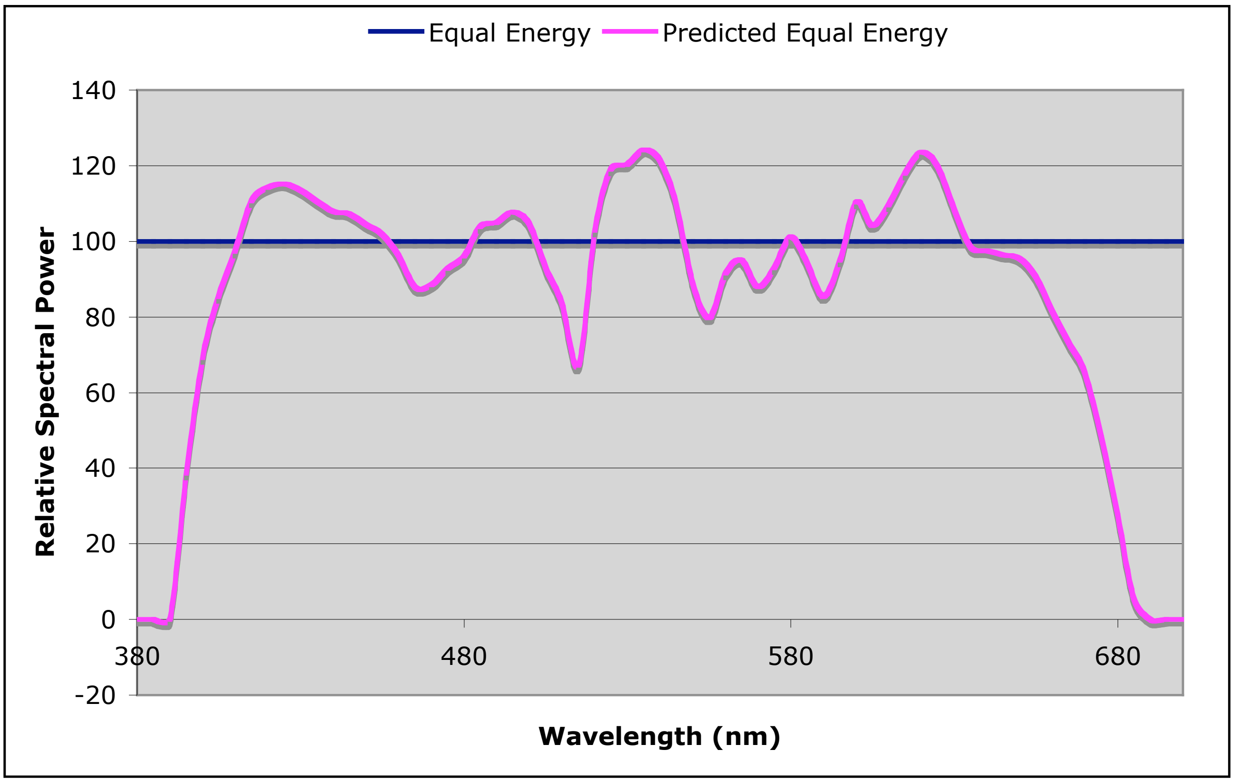


A simple spectral model was constructed by simply using the responsivities as basis functions and reconstructing spectra as weighted sums of them. This is analogous to the function of spectrophotometers in which each bandpass is a basis function. It is not a very accurate method for this application, but it generalizes completely to scenes of unknown spectral content. The model should only be used in such circumstances, and then with great care. It is always better to use the nine camera responses to find weights on a set of basis functions derived from the image content.

The first model is simply a fit of the measured spectral responsitivities to the equal energy spectrum (Ill. E). This can be thought of as a default model for a perfectly color balanced, 9-channel system. The fitted transformation is as follows. (Note this was done with an earlier set of responsivities so the details do not match the curves, but the basic concept and fit quality is appropriate. No mater what, for serious spectral imaging, a better reconstruction model should be derived.)

$$E(\lambda) = 544.3R(\lambda) + 42.41G(\lambda) + 233.2B(\lambda) - 877.7R_{FLD}(\lambda) - 40.73G_{FLD}(\lambda) - 295.3B_{FLD}(\lambda) + 265.1R_{ENH}(\lambda) + 40.72G_{ENH}(\lambda) + 45.19B_{ENH}(\lambda)$$

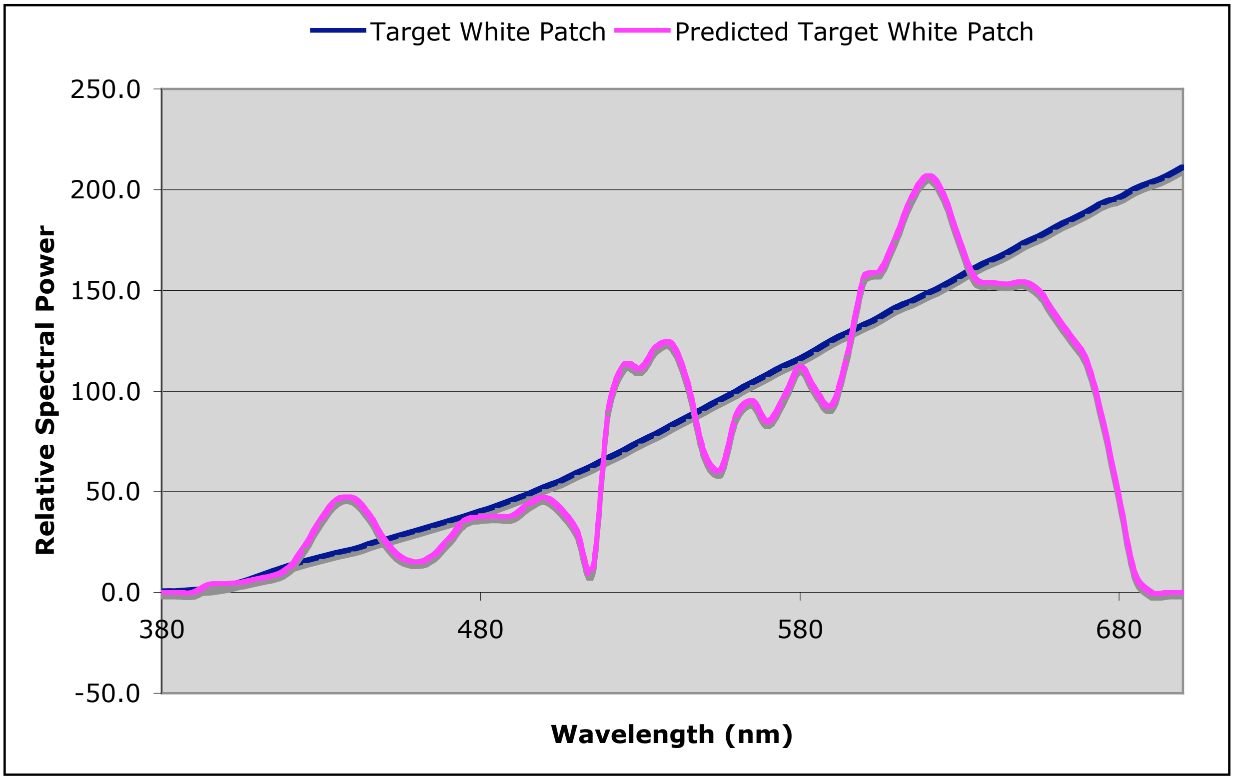
The fit is plotted below ...



The second model was similarly derived but was instead fit to the bright white patch from the Luxo Double Checker scene. The fit is ...

$$Target(\lambda) = 1034R(\lambda) - 174.9G(\lambda) + 462.2B(\lambda) - 1731R_{FLD}(\lambda) + 286.4G_{FLD}(\lambda) - 694.4B_{FLD}(\lambda) + 514.4R_{ENH}(\lambda) + 106.7G_{ENH}(\lambda) - 139.4B_{ENH}(\lambda)$$

And plots as ...



To relate to HDR image data, the Luxo Double Checker scene was shot with all three filters and the bright white patch sampled from the created HDR images (created from 9-stops of exposures). The RAW images were all imported with fixed D55 (daylight) white balancing using the Adobe Photoshop CS2 import software. No other adjustments were made. The sampled RGB values for each of the three images respectively were (161.1, 101.0, 28.76, 149.9, 32.90, 29.55, 188.0, 71.26, 30.54). To make a model to convert from image values to spectra, the fitted coefficients were divided by the image data to give new model weights that would be further multiplied by image values to obtain spectral images as follows (bold variables are image pixel values).

$$\begin{aligned} Pixel(\lambda) &= 6.418\mathbf{R}R(\lambda) - 1.732\mathbf{G}G(\lambda) + 16.07\mathbf{B}B(\lambda) \\ &- 11.55\mathbf{R_{FLD}}R_{FLD}(\lambda) + 8.705\mathbf{G_{FLD}}G_{FLD}(\lambda) - 23.50\mathbf{B_{FLD}}B_{FLD}(\lambda) \\ &+ 2.736\mathbf{R_{ENH}}R_{ENH}(\lambda) + 1.497\mathbf{G_{ENH}}G_{ENH}(\lambda) - 4.578\mathbf{B_{ENH}}B_{ENH}(\lambda) \end{aligned}$$

Again, this model should be used with great care as a large approximation. An accurate set of basis functions and weights should be derived for serious spectral imaging.