A CRT's Gamma (γ) verses the Human Vision System Model…Part I

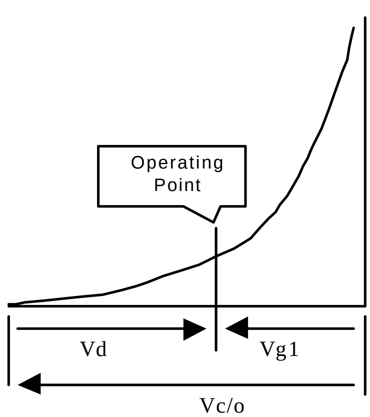
A CRT based display used for diagnostic purposes (primary reads) should be maintained in conformance with the DICOM Grayscale Standard Display Function (GSDF). The response characteristics of a CRT, however, do not naturally track with the way the eye responds to luminance energy. There are a whole host of variables associated with driving a CRT. This inherent flexibility coupled with differing circuit design choices, leads to one common outcome, there is a performance gap with the Human Visual System (HVS).

The video signal from the workstation or PC is measured in volts (0-.7 volts p-p) generated at the Digital-to-Analog Converters (DAC's). The display pre-amp and final output stage amplifies the voltage to drive the CRT's cathode. Volts drive (V_d) yields beam current, which is proportional to luminance at the screen. Luminance (L) output relative to V_d follows a power law relationship expressed by the formula…

$$L2/L1 = (V_d2/V_d1)^{\gamma}$$

Where Gamma (γ) is a dimensionless value that falls some where between 1.6 and 3.0 depending on the CRT design and biasing chosen.

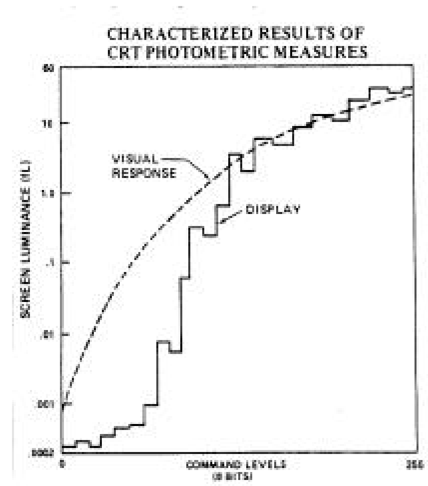
Calculating the gamma from only two points would need to be very specific as to what operating conditions they were measured under. As noted, a CRT's drive characteristic's (gamma) change depending on design and biasing, which is an engineering decision that takes a number of performance variables into consideration.



The operating point noted in the graph above shows the fixed voltage applied to the G_1 control grid (V_{g1}). This voltage, when added to the drive voltage (V_d) at black (off pixel), equals $V_{c/o}$ (volt cut-off). The $V_{c/o}$ will be within a range determined by the optics design, typically between 70 and 110 volts negative "relative" to the cathode. For 70 $V_{c/o}$, the G1 can be set to –20v (fixed, relative to ground) while the video amp is at +50. The video amplifier operates within positive voltages for optimum performance.

The drive voltage (V_d) at the cathode varies with image content over the range defined as black (cut-off) to peak white, i.e., black at +50v, and peak white at approximately +10v. The more luminance commanded, the less positive the cathode, causing more current flow to the screen (I_c). The selection of 70 or 110 volts for cut-off changes the performance characteristics, i.e., location on the curve alters the measured gamma. Operating close to maximum current potential (I_c) is not desirable; beam aberrations and damage would be the result.

The CRT response plotted against the HVS model illustrates how the initial response, just above cut-off, lags behind the human visual system model.[1]



The worst part of the gap falls below where black is generally defined in operational environments. Typical settings for 1k line referral/clinical displays is approximately 0.5fL and a primary diagnostic 2k line at 0.05fL. Since the remaining gap can still contain valuable tonal information, a corrective scheme is advisable for complex medical images.

Five Megapixel displays can employ variable gain pre-amps to calibrate the display luminance response and when matched to a medical grade video card with a Look-Up-Table, the DICOM GSDF can be maintained with confidence. Low cost 1k line displays are not compensated, but can be DICOM compliant with the use of medical grade video cards.

1. Stewart Briggs, SPIE Vol 762, page 158, 1987