The pal (phase alternating line) system

Technology, Computer

The human eye is a complicated piece of biology developed over millions of years of evolution, its operation is non-linear and differs from person to person. Before anyone can design a system that involves visual interaction with humans they must understand the operation of the eye.

The PAL (Phase Alternating Line) system interacts with the human eye effectively and appears to give an accurate representation, with colour and detail of the image it is trying to reproduce. It is, however, simply not the case that images are transmitted as seen by the camera and reproduced accurately on our televisions, this would require huge bandwidth and be expensive. Indeed this would not be an efficient way of achieving colour television, as much of the detail and colour would be un-appreciable to the human eye, and a waste on all but the most expensive televisions.

The PAL system tries to optimise performance while minimising bandwidth by incorporating factors known about the operation of the eye.

Persistence of vision for humans is around 30Hz, a PAL system takes advantage of this by transmitting at 50Hz but refreshing only every other line, in effect the whole picture refreshes at 25Hz but due to the raster effect the eyes see no flicker, as might otherwise be the case. This phenomenon was witnessed in question 6 of Part 1 A of the lab. The eye is fooled into seeing continuous pictures, when the reality is in fact a series of stills refreshed 25 times a second.

Another feature of the eye is its inability to respond equally to all colours, the eye is most responsive to yellow/green wavelengths of light. Differences in colour at the red part of the spectrum are harder to judge, with sensitivity to blue light wavelengths being the worst of the primary colours. This is shown graphically by Fig 1, one can see that the relative intensity is higher at the green/yellow part of the electromagnetic spectrum.

Fig 2 shows the range of colours that the human eye is capable of viewing, within this is a triangle that represents the colours that a television is capable of reproducing, a colour is possible if it lies within the triangle. One can see that all colours are not possible, this is due to the compression of the actual signal to reduce the bandwidth needed to transmit the signal, and the phosphors that generate colour in the television tube. But the reduced number of colours available is more than enough to give an detailed representation of any image.

The PAL television system was designed to give colour to television broadcasts while still being compatible with the old black and white system. To do this engineers kept the majority of the old system and modulated a subcarrier-wave with the colour information on-top of the luminance signal. This is not the most accurate way of doing it, but takes into account that the eye is much more sensitive to luminance (detail) than chrominance (colour). These factors being detected by rods and cones respectively and there is a lot more of the former within the eye.

It is important to remember that all colours can be made up from differing mixes of the three primary colours: red, blue, green. The eye does not see the individual colours, rather the resultant of the component wavelengths mixed together. This is shown roughly in Fig 3. PAL TV uses this fact to encode the incoming picture into effectively three separate pictures for colour, and one picture containing luminance information. When the three colour information pictures are overlaid on the luminance picture the system should reproduce the original image with just enough detail to give a clear and detailed picture (although this is clearly a degraded image from the original).

Cameras are used which split the input into primary colours using dichroic filters, these allow reflection of one colour while appearing transparent to others. The input signal will be split up into its component primary colours, red(R), blue(B), green(G), each element going to its own vidicon tube. The electrical signals from these tubes are then processed for transmission, the system can be seen in Fig 4.

The luminance of a particular part of a picture is made up from the addition of the primary colour intensities, but not in equal parts. It consists of 11% of the blue signal, 30% red, and 59% of the green signal. This is caused again by the non-linear sensitivity of the eye to different wavelengths. Vidicon tubes have a linear response to light brightness and voltage given, unfortunately the electron tubes in televisions do not so the luminance signal needs to be gamma corrected before transmission.

Within the camera the luminance(Y) is calculated using the above ratios for each of the colours, the signal is then gamma corrected and transmitted. The information from each of the vidicon tubes is processed and also transmitted but instead of sending the actual signals R, B, G, it is the R-Y and B-Y calculated signals that are transmitted. In this way the third and most important signal G can be calculated by the receiving television. The reason that these two signals were chosen (as one could choose any of the two) is due to the colour being mostly (59%) made up of green, this would give a small G-Y value that would be more susceptible to noise when transmitted. The calculation of the G signal from the other two signals is preferred as errors are minimised for the most important part of the signal.

The colour information is less important than the luminance information as previously stated, as such this is given less bandwidth of the overall signal. This can be seen in Fig 5. We saw in Part 1 B of the lab that the colour information is contained within a subcarrier wave that is modulated onto the luminance signal. It is the phase difference of the two colour signals (R-Y and B-Y) that have been modulated in quadrature onto the subcarrier that determine colour. In reality they are weighted before being amplitude modulated, then suitably restored to their former values when decoding takes place in the receiving television.

In Part 1 C of the lab we were able to see a complete phase shift in the colour information signal when switching from one raster to the next (from odd lines to even lines). The even lines on the screen gave a certain colour for a positive phase difference, where as for the odd lines of the screen (the second raster) the same colour would be formed from a negative but equal phase difference.

This is done to reduce the effect of errors that occur in the signal. For example magenta on the even lines with a slight error of phase might give rise to a little more blue in the signal than was required, but on the even lines the same error in phase for magenta would give rise to more red in the signal than was required. The eye again does not see all this but sees the resultant adding of these errors, from Fig 3 one can see that red and blue add to give magenta. The errors add up to give the desired colour anyway. It is this way of averaging the signal and alternating of the phases to represent colour between the different lines that hue errors are corrected, giving a seemingly accurately coloured image.

In Part 2 of the lab we were asked to view different colours of diagnal lines and note when they appeared to be indistinguishable, or when there appeared to be no diagnal lines, just a block of colour. This is important knowledge to television makers as it tells them just how much colour information they should put into the signal. It is known that televisions do not look that good when close up, but people do not watch them from very close up. There is normally a distance of at least 1. 5m between a person and a TV, it is at this distance that designers should concentrate on giving a clear picture to the viewer. If one knows that two colours next to each other viewed from over 1m away do not appear as two colours but rather as one then transmitting them as two separate colours is a waste of time, bandwidth, and leading from this money. Carrying out tests such as this will provide information to the designers about how much colour information they need to transmit, so enabling them to reduce it just above an acceptable level.