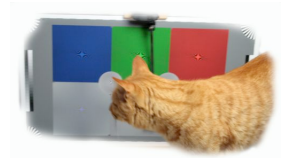


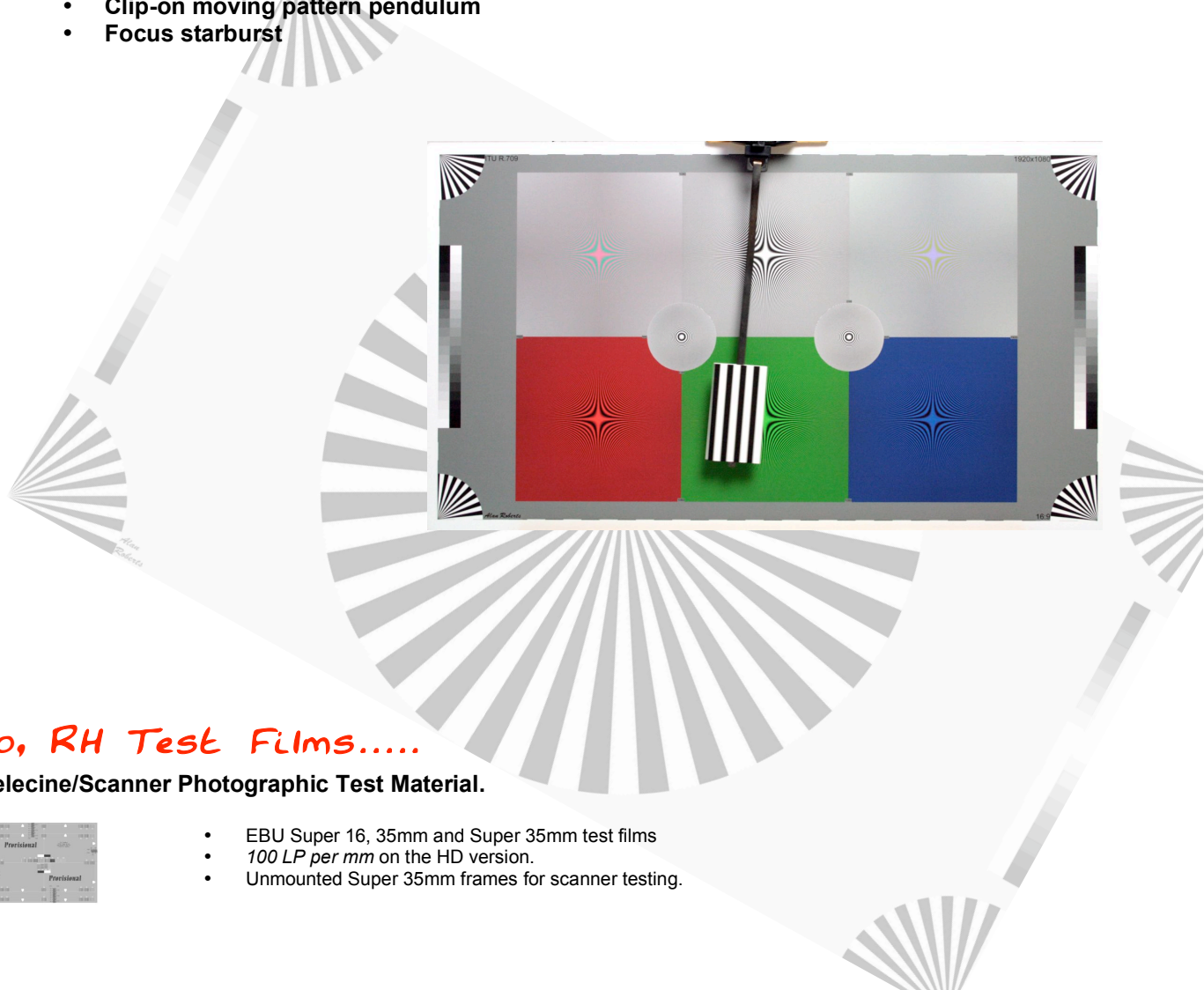
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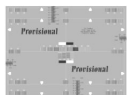
In conjunction with Alan Roberts, BPR have developed a method of printing sine wave patterns without visible alias, up to a resolution of 4k lines on a 500mm wide 16 x 9 chart.

- Hyperbolic Zone Plate – Has constant line and vertical frequencies on Luminance, RGB and Component elements
- Updated HD version of TC57 with super black
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The Zone Plate as a television test chart

This enormously useful test chart can reveal many aspects of camera and system performance in a highly graphic way. Mathematically, it is an exploration of the Phase Space of spatial frequency (i.e. it explores all the possible signal frequencies in all the possible directions and combinations), and can be tailored to match the resolution limits of the video system under test. It can have many forms, each suited to some measurement process, the two most common types of pattern are Circular and Hyperbolic, and can be of Cosine or Square wave-shape.

In principle, you might expect that a camera should be able to reproduce frequencies all the way up to the Nyquist limits set by the pixel and line counts, horizontally and vertically. But this is highly undesirable because frequencies at and near these limits are easily confused with frequencies above the limits. The process is called “aliasing”, where frequencies higher than the Nyquist limits are folded back on themselves. You can see the onset of this in these examples, where half null-centres are visible at the edges. In a television system, these aliases will move in anti-phase (opposite direction) to the main picture when it moves, causing a general “busy-ness” which can confuse a video compressor. In any normal camera, the lens and sensor will provide some form of low-pass filtering, so the aliases should not be as visible as they are here, but the filtering in many cheap cameras is far from ideal, and aliases will be present, causing what looks like noise or compression artefacts.

Hyperbolic

In this form, the pattern is drawn with constant horizontal frequency horizontally across the pattern, and constant vertical frequency vertically down it. The actual frequency on each line or column is constant and is proportional to the distance from the centre.

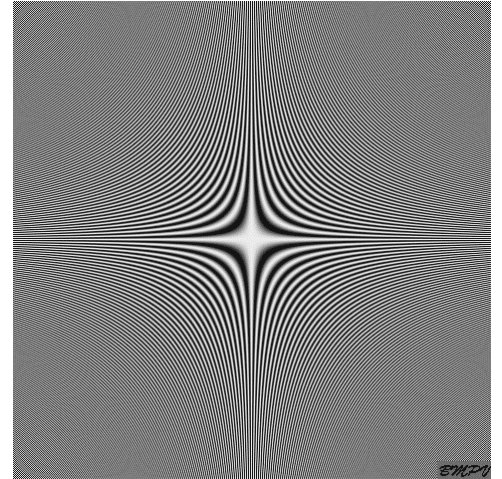
The equation of the hyperbolic zone plate is:

$$\vartheta = kx^2y^2$$

Where θ is the phase of the sinusoid, k is a scaling constant, and x and y are the pixel coordinates measured from the centre.

Contours of constant-phase are hyperbolic. Thus, you point a camera at this chart, and view the video signal a waveform monitor, the video signal will consist of television lines each containing bursts of a constant horizontal frequency. Therefore, selecting single lines (or columns) produces continuous bursts of single frequencies and it is easy to measure the amplitude and therefore the frequency response.

While this seems at first to be rather useful, the circular pattern has some distinct advantages when it comes to analysing camera design and performance, since the circular pattern seems to be better matched to human perception. Nevertheless, the hyperbolic pattern is much easier to explain.



Circular

In this case, both horizontal and vertical frequencies are separately proportional to the radius. Thus, the frequency sweeps linearly from the centre in all directions. While there are no constant-frequency bursts as in the hyperbolic version, the circular shape is much more closely matched to the human perception of resolution which has the same frequency response in all directions. The equation of the circular pattern is:

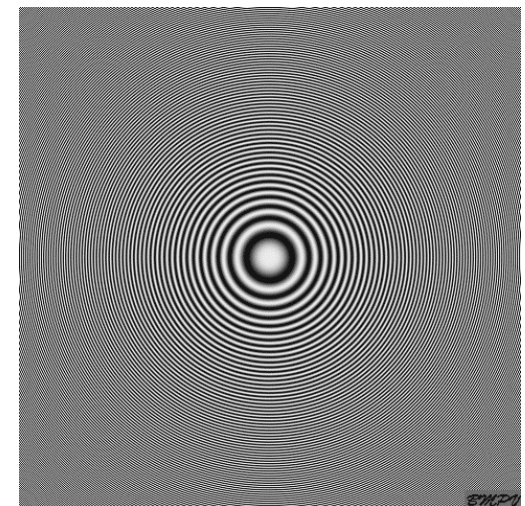
$$\vartheta = k\sqrt{x^2 + y^2}$$

In this example, the bounding is square, and so the maximum frequencies extend into the corners, reaching $\sqrt{2}$ times the horizontal or vertical limit. This is not useful in human terms, since vision limits are circular, but television systems tend to have independent horizontal and vertical limits, set by the pixel and line dimensions. However, it seems aesthetically more pleasing to have the chart circularly bounded.

You can see aliasing effects in this example as faint half-circular null-zones centred at the horizontal and vertical extremes. This is because the frequency content remains firmly at 100% amplitude all the way up to the Nyquist limit, where one cycle of the frequency occupies exactly 2 pixels or lines.

Practical example

Zone plates are very useful for identifying the effects of filters, Bayer-pattern decoding, sub-sampling, down-conversion, detail enhancement, lens performance, and a variety of other parameters. In practice, the circular zone plate is often used in a bounded form, because lenses have a circular MTF (i.e. the frequency response drops off radially), and human vision also has a circular

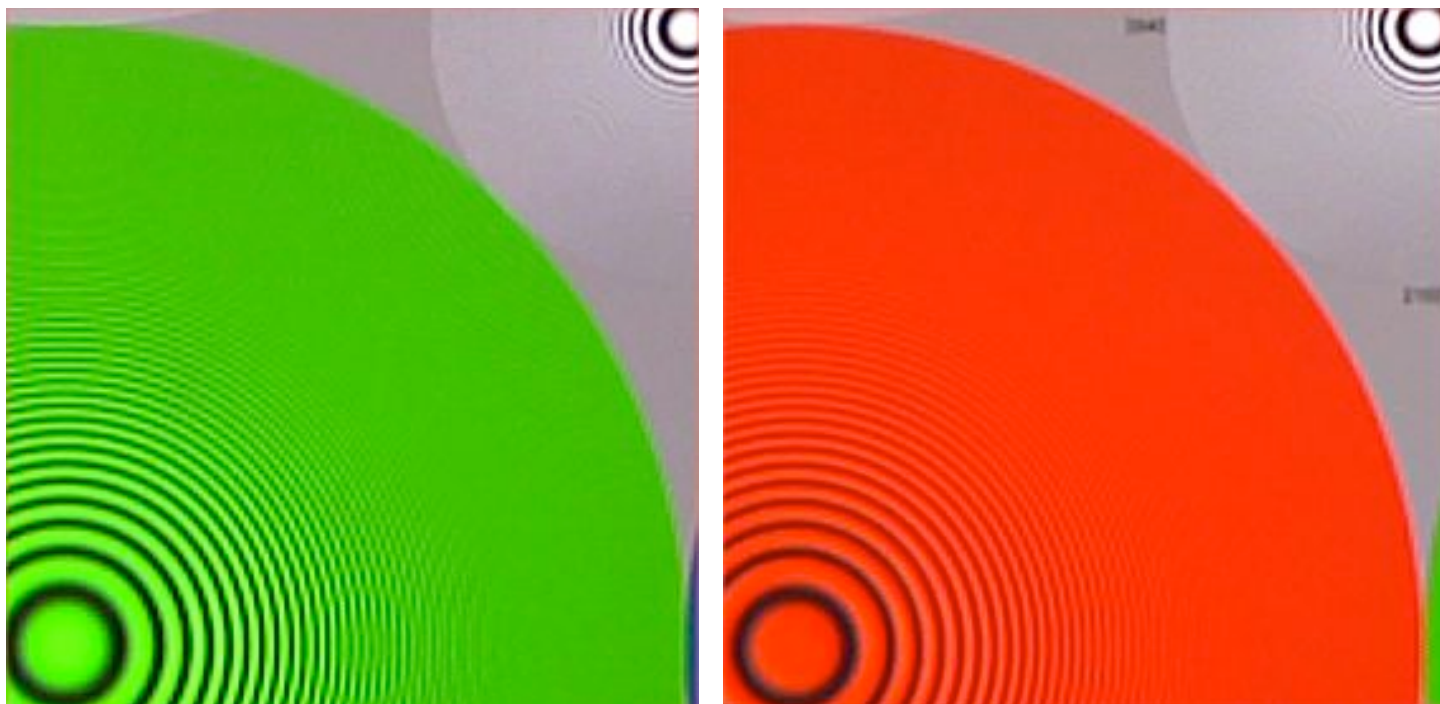


MTF, so any imaging system need not have great diagonal resolution into the “corners”.

This part-frame was “grabbed” from a measurement session on a real HDTV low-cost video camera, using a bounded circular zone plate test chart, with cosine wave modulation. It shows one quadrant of one pattern. There is coloured aliasing at the horizontal and vertical limits, and grey-scale aliasing in diagonals. This indicates that the camera has a single sensor, with less-than-perfect decoding of the pixel Bayer pattern. There is little or no modulation at the extremes, both horizontally and vertically, which establishes that the camera lens is reasonably well matched to the camera. This also reveals that there is no optical filter in the camera since the response tails off very gradually, typical of a lens but not the sharper cut-off of an optical filter. In a more costly camera, the lens would be sharper and a filter included to stop the aliasing.

There is considerable aliasing at high diagonal frequencies, and the positions of centres of the null-zones, confirm that that the sensor pixel count matches the format (1920x1080 in this case), i.e. the camera cannot be expected to deliver resolution to fill the video system format.

To confirm these conclusions, take a look at quadrants from the red and green patterns.



Green shows the same limits and aliasing as Y, while red limits and has aliases at half the system limits, 960x540. This confirms that the sensor is a single Bayer-patterned device with 1920x1080 pixels. The coloured aliasing in the Y pattern comes from the aliasing in both red and blue. Green does not have quite the expected limits because the camera does not give access directly to the RGB signals, these examples have been coded into YP_bP_r with the inevitable bandwidth reductions in the 4 colouring channels.

Zone Plate versions

The design and layout of these charts has been made as flexible as possible. They can be customised in many ways, to accommodate special requirements. However, there are two basic versions:

In 16x9 format charts, there are two rows of three patterns. In the most complex form, the top row has patterns for P_r , Y and P_b , calculated for either SDTV (ITU601 coding) or HDTV (ITU709 coding). The bottom row has patterns for each of R G and B.

In 4x3 format charts, there are two rows of two patterns. There are patterns for a Y and G, and two split vertically between R B and patterns calculated to produce modulation only in the P_b and P_r channels. While the colours are not guaranteed, the colour separation is good enough to be able to examine the camera and system performance well enough.

There are also smaller-sized patterns on the bounded circular charts, calculated to explore exactly double the system Nyquist limits. These are for quick assessment of the camera and system performance when presented with frequencies that are well above the system limits, frequencies that should be suppressed either by the lens or by specific optical filtering.