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HVS low perception of FPN and PRNU Noise in Pyramidal CMOS Imager

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Abstract

Frequently, video communication system, such as TV, is thought to be composed of an acquisition system (camera), channel communication and display device (TV set). In reality even the human visual system (HVS) or the viewer is also considered to be a part of this 3-dimensional data (2-dimensional image array + 1-dimension for time) communication system. This is because of the spatio-temporal limitations of the HVS of the viewer in resolving the transmitted data and which the engineer has to include in constructing this communication system to optimize his/her design. As an example of this fact, one may mention the use of the persistence of vision in HVS which reflects the fact the human vision does not refresh instantly the acquired image but take about 1/24th of a second to do so and that is why television frame rate is above this threshold to blend consecutive images in one smooth picture.

In this present paper we will use a spatial limitation of the HVS known as the oblique effect. It is well known that spatial vision in HVS as well as in many animal species is not anisotropic being more sensitive to stimuli (spatial patterns) that are oriented vertically or horizontally compared to those obliquely oriented (45° and 135°). This phenomenon is shown in Fig 1. On the other hand, in CMOS imagers and due to the mismatch in the photo-signal transportation path creates vertical stripes at the output image especially after correlated double sampling is applied. These mismatches are caused by the variations that the generated photo-signal faces on its path off-chip such as those in pixel source follower, beside the mismatch of the offset and gain of the column amplifiers, double sampling circuits and other column-based systems. This also clearly shown in Figure 2 that includes the Fourier spectrum of a classical CMOS imager fixed pattern noise distribution which clearly shows the dominance of column-to-column mismatch noise causing the vertical stripes. In pyramidal CMOS imagers the columns are replaced by diagonal buses leading to an obliquely distributed FPN noise as depicted in Figure 3. Consequently, using the oblique effect fact we show that the pyramidal CMOS imager FPN noise is less perceptible. For this end, we constructed a spatial filter based on empirical data of the photo response of receptive field cells at the retina's central part known as the fovea. The constructed spatial filter has included the oblique effect by keeping the bandwidth of the cardinal axes (horizontal and vertical) bigger than the oblique axes at 45° and 135°.

After Constructing the HVS spatial filter we built constructed another exactly similar filter but tilted 45° that is similar to tilting the human ace by 45° as shown in Figure 4. By applying both filters on an FPN image and subtracting the response of the normal HVS spatial filter from that of the tilted HVS spatial filter, we wanted to see if the oblique FPN noise has been captured by the tilted filter compared to that captured by the normal HVS spatial filter. This in fact was verified and shown in Figure 4.

The present paper goal is to include the HVS performance in evaluating future imager especially if the imager output is to be visualized to human observer. In this sense, the race of lower noise imagers may be ended if the noise is not perceived the HVS at first place. In other words, this work tries to answer how much is enough in the designing low noise imagers.

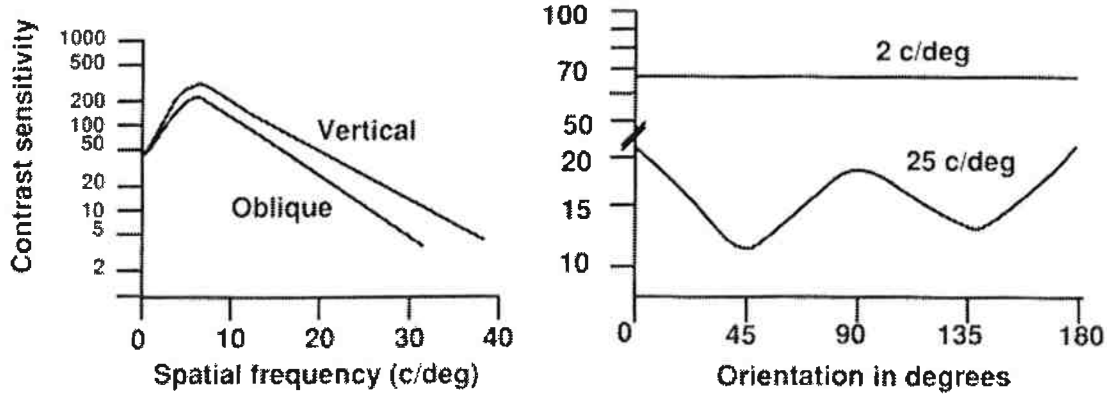

Figure 1 Contrast sensitivity of HVS as function of spatial frequency showing oblique effect arising at high frequencies.

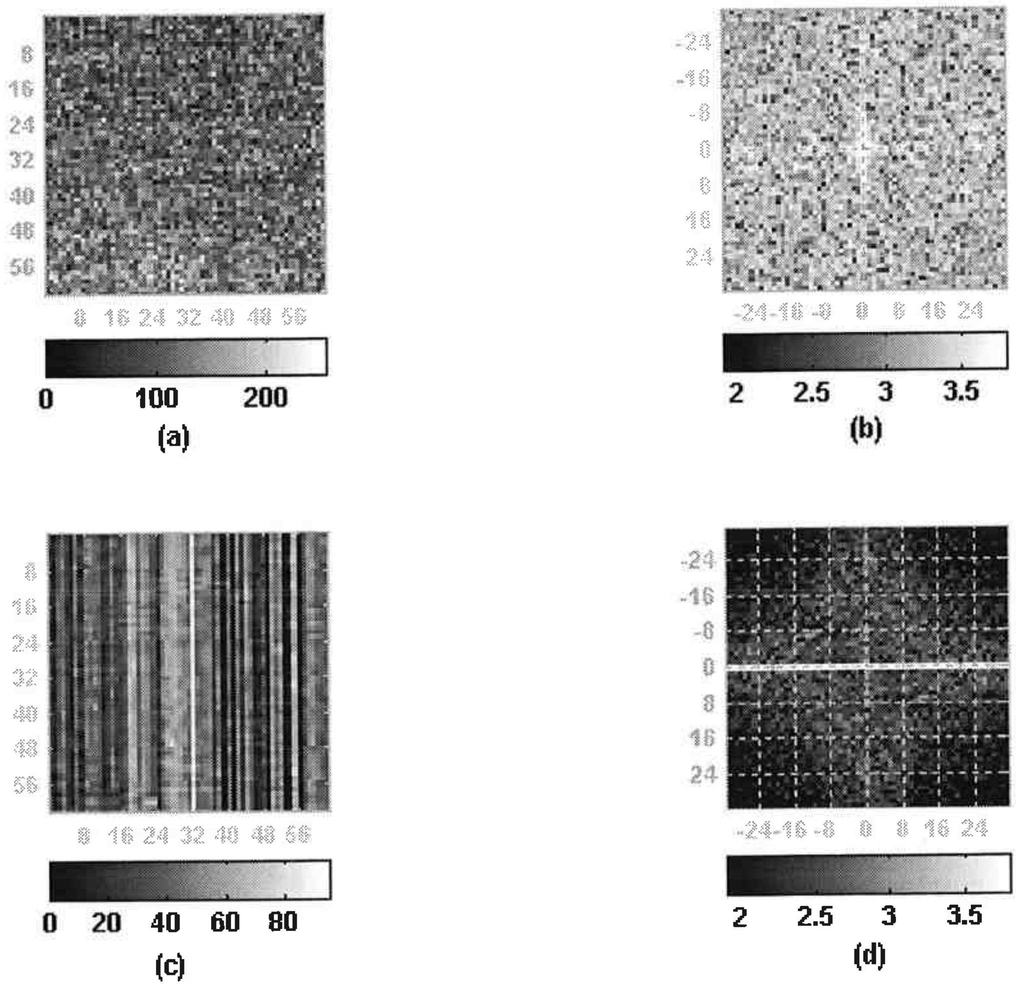

Figure 2 FPN noise topology in classical CMOS imager sensor.

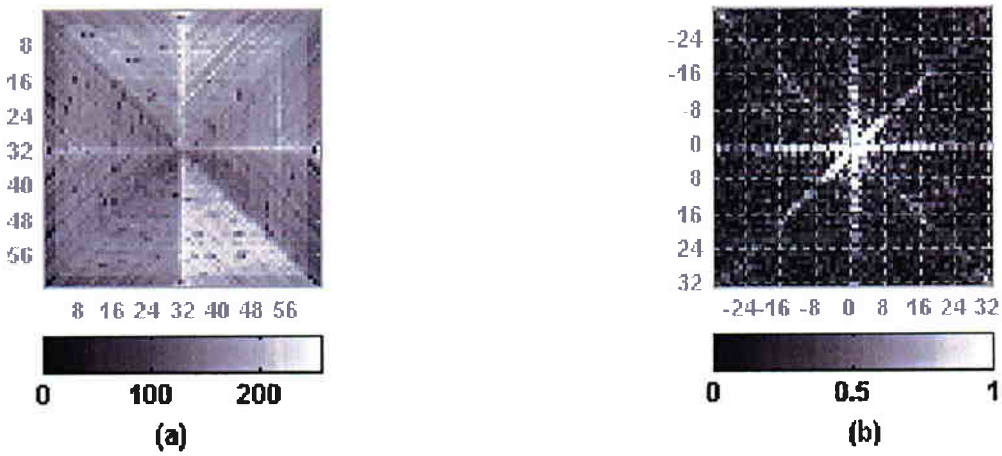

Figure 3 FPN Topology in a 64x64 Pyramidal CMOS Image Sensor

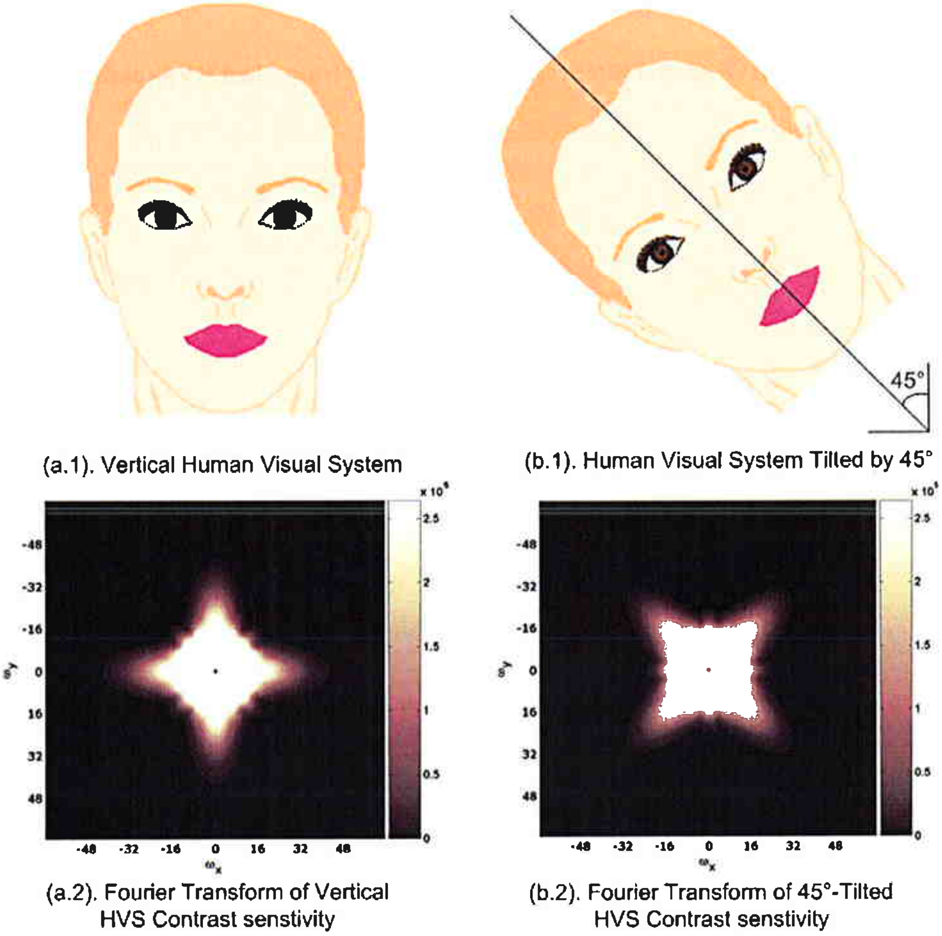

Figure 4 Pyramidal FPN noise perception by HVS experiment

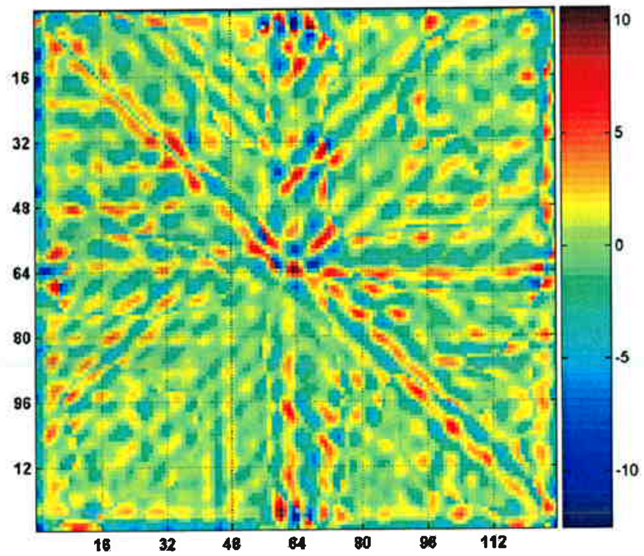

Figure 5 Normal HVS spatial filter response subtracted from tilted HVS spatial filter.