Chapter 7

Effect of Saturation on Pattern noise

IN this chapter, the Reichardt correlator model is extended to include an additional non-linearity which has been seen to be present in the fly visual system and its effect is studied on the contrast dependance of the response and an attempt is made to understand its influence on pattern noise. Experiments are carried out by adding this compressive non-linearity at different positions in the model as has been postulated by previous works and comparison of the physiological data with modelling results is carried out.

7.1 Saturation or Compressive non-linearity

Both simple and elaborated Reichardt correlators show an increase of response amplitude with stimulus contrast. The neural and behavioural responses of the fly display such a dependence only at very low contrasts. As contrast increases above a few percent, the response begins to level off due to a static, compressive non-linearity which is termed as contrast saturation [Dror, 1998]. This is due to limitations in the range of responses that can be signaled by physiological mechanisms.

Earlier work on contrast saturation has shown that it can help in decreasing the dependance of the correlator response to contrast, thereby enabling more reliable velocity estimation [Dror, 1998]. So here the effect of saturation is also tested in the contrast response of the model by implementing saturation at different positions in the model and testing it at different contrasts.

7.2 Pattern Noise

Differences in the structure of scenes result in variations in the correlator response termed as the pattern noise. The pattern noise here is not a random source of noise. It is most likely due to excitation of individual local motion detectors. Arrays of such detectors could provide spatially distributed information which is integrated at or before the level of wide field motion sensitive cells such as HS. Spatial pooling from just a single pair of HS cells might be enough to smooth out the pattern noise [Rajesh et al., 2005b].

7.2.1 Pattern noise at different contrasts and different speeds

In order to understand the effect of pattern noise at different speeds and at different contrasts, physiological and modelling experiments [Rajesh et al., 2005c; Rajesh et al., 2005b] are carried out using the same image shown in Figure 7.1, at high and low contrasts at speed 180 degrees per second, which is close to the optimum velocity in *Eristalis tenax* and at a higher speed of 720 degrees per second.

7.2.2 Electrophysiological results

Electrophysiology experiments [Rajesh et al., 2005c] are carried out at the speeds 180 degrees per second and 720 degrees per second both at high (contrast of 1) and low

Fig. 7.1. The panoramic natural image given as stimulus to the EMD model. A panorama of the image is formed by 'warping' 12 image tiles at 30° intervals to remove lens distortions and then by wrapping its ends together using Apple Quicktime VR software on a Macintosh computer.

contrasts (contrast of 0.2). This gives an understanding on how pattern noise is affected at different contrasts and at different speeds. Figure 7.2 and Figure 7.3 shows the response of a HS neuron at two different speed and at two different contrasts.

Figure 7.2 shows the effect of pattern noise on response of a single fly wide-field motion detecting neuron (HS cell) to a natural image (see Figure 7.1) with the image presented is moving at high speed of 720 degrees per second and low speed of 180 degrees per second at 8 different initial phases, each 45 degrees apart at a very low contrast of 0.2. For each combination of velocity and image, part (a) shows three responses to identical experimental conditions. Part (b) shows the mean of at least three responses at each of several stimulus positions. Part (c) show the mean response in black and the standard deviation of the response around the mean in gray. The responses were 'phase aligned' by compensating for the position change before averaging. The 'time aligned' response shows the individual responses at each initial position averaged without compensating for position change [Rajesh et al., 2005c]. Inspection of the individual responses and the phase aligned response indicates that pattern noise is more significant at low contrasts.

Figure 7.3 shows the effect of pattern noise on response of a single fly wide-field motion detecting neuron (HS cell) to a natural image (see Figure 1), with the image presented moving at high speed of 720 degrees per second and low speed of 180 degrees per second at 8 different initial phases, each 45 degrees apart at a high contrast of 1. For each combination of velocity and image, part (a) shows three responses to identical experimental conditions. Part (b) shows the mean of at least three responses at each of several stimulus positions. Part (c) show the mean response in black and the standard deviation of the response around the mean in gray. The responses were 'phase aligned' by compensating for the position change before averaging. The 'time aligned' response shows the individual responses at each initial position averaged without compensating for position change [Rajesh et al., 2005c]. Inspection of the individual responses and phase aligned responses indicates that pattern noise is more prominent at higher speeds.

Figure 7.2 and Figure 7.3 indicates that the shape of the pattern noise is also affected at different contrast which poses the question to whether there are more factors which could be affecting pattern noise and this has lead to more investigation on whether saturation (compressive nonlinearity) which is proved to be present in the fly visual system could have a role in influencing pattern noise. So in the model, the results are tested with saturation which is shown in the next subsection.

7.2.3 Modelling results

In order to understand the variation of pattern noise at different contrasts and speeds, modelling experiments were done using our elaborated EMD model [Rajesh et al., 2005b] at the speeds 180 degrees per second and 720 degrees per second both at high (contrast of 1) and low contrasts (contrast of 0.2) with the same image as used for previous experiment. The model without saturation is compared to the model which has output saturation (saturation implemented on the mean correlator response) to investigate the effect of saturation on pattern noise. Figures 7.4 to 7.7 shows the simulated response of the model with and without saturation.

Figures 7.4 shows the simulation results obtained by running the model with and without implementing output saturation, at 720 degrees per sec at a low contrast of 0.2 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the results obtained with and without adding saturation shows, that addition of saturation has no effect at low contrasts as the response saturates only at higher contrasts.

Figure 7.5 shows the simulation results obtained by running the model with and without implementing output saturation, at 180 degrees per sec at a low contrast of 0.2 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the results obtained with and without adding saturation shows, that addition of saturation has no effect at low contrasts as the response saturates only at higher contrasts.

Figure 7.6 shows the simulation results obtained by running the model with and without implementing output saturation, at 720 degrees per sec at a high contrast of 1 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the model with saturation and without saturation shows that saturation implemented at the out put affects the pattern noise at high contrast by reducing the magnitude of the response and changing the shape of the pattern noise as can be seen from the phase aligned response

Figure 7.7 shows the simulation results obtained by running the model with and without implementing output saturation, at 180 degrees per sec at a high contrast of 1, using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the model with saturation and without saturation shows that saturation implemented at the output affects the pattern noise at high contrast by reducing the magnitude of the response and changing the shape of the pattern noise as can be seen from the phase aligned response

Comparison of the model with saturation and without saturation shows that saturation, implemented at the output affects the pattern noise at high contrast by reducing the magnitude of the response and changing the shape of the pattern noise, as can be seen from the phase aligned response in Figure 7.6 and Figure 7.7. And from Figure 7.4 and Figure 7.5, it is seen that saturation has no effect whatsoever at low contrasts with the saturated and unsaturated results being the same at low contrasts, as the response saturates only at higher contrasts. The differences that can be seen in the modelling and physiological results could indicate that saturation may be present at other points other than the output stage or more than one point in the fly motion pathway.

7.3 Effect of Saturation on pattern noise

In order to understand the effect of saturation on pattern noise, the elaborated Reichardt model [Rajesh et al., 2005b] is tested by incorporating saturation at different positions on the model and it is found that addition of saturation at different points result in changing the shape of the pattern noise. When the electrophysiological results are compared with the modelling results it is seen that there is some kind of compressive non-linearity present in the system, which causes changes in the pattern noise. So saturation was implemented at three positions in our model. One is at the photoreceptor output, that is after the spatial filtering and the next it was implemented at the correlator arms at the multiplication stage and finally it is also implemented at the output on the mean of the correlator output. The modelling results for the each of this case and with different combinations of them at high and low contrasts is given here.

7.3.1 Saturation at the correlator input

Saturation of the visual signal first occurs in the photoreceptors, which respond roughly to logarithm of luminance [Laughlin, 1994]. Saturation reduces relative error partly by reducing contrast difference from one region of the image to another. It is seen in flies that this saturation occurs primarily after linear pre-filtering but before the multiplication operation indicating that contrast saturation must take place after elimination of the mean light intensity from the signal [Egelhaaf et al., 1989; Dror, 1998]. Saturation is modelled here by including a compressive non-linearity such as a hyperbolic tangent function of the form, $\rho(C) = \tanh(C)$.

Figure 7.8 shows the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. As it was done before, in the phase aligned method, each phase delayed response is aligned by shifting each response along the x-axis with the data obtained for phase zero and then we average it. The pattern noise present is clearly seen. In this case, saturation is implemented at the correlator input after the spatial filtering stage.

7.3.2 Saturation at the correlator arms

It is seen that saturation also takes place on both the delayed and un-delayed arms of the correlator with saturation on the delayed arm following the delay filter [Egelhaaf et al., 1989; Dror, 1998]. So based on this, we have implemented compressive nonlinearity before the multiplication operation on both correlator arms.

Figure 7.9 shows the response of the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. In this case, saturation is implemented at the correlator arms at the multiplication stage. It is seen that the shape of the pattern noise is different from the previous case where saturation is implemented at only the input stage.

7.3.3 Saturation at the output

The outputs of the wide field neurons are also found to saturate due to shunting of the membrane potential [Single and Borst, 1998].This is introduced as a compressive non-linearity following spatial integration [Dror, 1998]. Such an effect will flatten the peaks of the velocity response curves effectively allowing neuron to use more of its dynamic range to signal low velocities. So based on this, saturation is implemented at the output stage of the model.

Figure 7.10 shows the response of the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. In this case, saturation is implemented at the output stage on the average EMD response. Note that the shape of the pattern noise is different from the previous two cases.

The effect of saturation is also tested at more than one points in the model, on pattern noise. Figure 7.11 shows the phase aligned simulation results obtained by running the model at 180 degrees per sec at contrast 1 using the same image, at 8 different initial phases, each 45 degrees apart. In the first case, saturation is implemented only at the output stage that is after the outputs of the EMDs are averaged. In the second case, saturation is implemented at the correlator arms before the multiplication stage along with output saturation. And in the third case, saturation is also present at the input, after spatial averaging, along with saturation at the arms and output saturation. It is seen that the shape of the pattern noise changes when saturation is implemented at more than one points with more bumps seen when more saturation is added. This indicates clearly that compressive non-linearity present in the insect visual system affects the pattern noise. It is also clear that the position of saturation in the visual system of insect also has an influence on pattern noise.

7.4 Effect of Saturation on Contrast dependance

Studies carried out by Dror reveal that similarities between natural image power spectra lead to predictable peak response velocities and to similarities in the shapes of the velocity response curves for different natural images. The primary difference between the curves, their overall amplitude, results from contrast differences between images. In order to use mean correlator response as a reliable indicator of velocity, the visual system needs to compensate for these contrast variations [Dror et al., 2000; Dror, 1998]. One possibility is contrast saturation early in the motion detection pathway, which eliminates significant differences in contrast [Dror, 1998] and alternatively some form of adaptation (contrast adaptation) in the visual system, may work to remove contrast difference between the images [Harris et al., 2000; Rajesh et al., 2002].

Contrast saturation has been found to affect the dependance of the correlator response to contrast [Dror, 1998]. In order to test the effect of saturation on the contrast dependance of the correlator response, the model is tested by implementing saturation at different points in the model. First saturation is implemented only at the input stage after spatial filtering and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is shown in Figure 7.12. Implementing saturation only at the input is found to decrease the dependance of the correlator response on contrast.

Saturation is then implemented only at the correlator arms and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is shown in Figure 7.13. It is seen that the addition of compressive non-linearity only at the arms has a remarkable effect on reducing the contrast variations. Saturation implemented at the correlator arms causes more squashing of the response there by decreasing the dependance of the response to contrast further.

And finally saturation is implemented only at the output of the correlators and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is shown in Figure 7.14. It is seen that the addition of compressive non-linearity at the output alone has less affect on reducing the contrast variation when compared to the implementation of saturation at the correlator arms. So though saturation at the output reduces the dependance of the response to contrast it has less affect than saturation implemented only at the arms. This could be because this saturation is implemented globally on the mean correlator response where as the saturation implemented at the input and the at the arms is implemented locally on individual local motion detectors.

7.4.1 Saturation at more than one points in the model

Here saturation is implemented at more than one points. In the first case, saturation is implemented only at the output of the correlators and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is shown in Figure 7.15. In the second case, saturation is implemented at the output as well as the correlator arms and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is shown and finally saturation is implemented at the output, at the correlator arms and the photoreceptor output and the response of one row of EMDs at three different contrast (1, 0.5, 0.1) is given. It is seen that the when the compressive non-linearity is added only at the output, the variation of the response is huge with the lowest contrast giving very low response and the highest contrast giving a very high response. But addition of saturation at the arms decreases the variation of the response to contrast and the further addition of saturation at the input further reduces the effect of contrast on the correlator response suggesting saturation could have a key role in reducing the contrast dependance in fly motion pathway thereby helping them to signal velocity accurately [Rajesh et al., 2005d].

7.5 Conclusion

In this chapter, a study is conducted on the effect of saturation on the contrast dependance and on the pattern dependant noise. Saturation is implemented at different points where it can be found in the fly visual system and its contribution individually and combined together on the response of the EMD array model is observed. It is noted from experiments that addition of saturation decreases the effect of contrast on the correlator response. It is also found that the shape of the pattern noise changes when saturation is implemented at more than one points indicating that the compressive non-linearity present in the insect visual system affects the pattern noise. It is also noted that though saturation at the output reduces the dependance of the response to contrast, it has less effect than saturation implemented only at the arms. This could be because this saturation is implemented globally on the mean correlator response whereas the saturation at the input and at the arms are implemented locally on individual motion detectors. This clearly indicates that the position of saturation in the visual system of insects also influences pattern noise.

The physiological results are compared with modelling results, and it is seen that the model is able to mimic most of the properties of the physiological data in most of the cases. Even though the exact location and contribution of saturation to the fly visual system is not known, from the preliminary results here, it is clear that saturation could have a key role in decreasing the pattern noise and contrast dependance of the correlator response thereby enabling the fly visual system to signal velocity accurately.

In the next chapter, the performance of the model is discussed with and without elaborations to understand the affect of each elaboration on the model and to study what impact each of the additions have on the model.

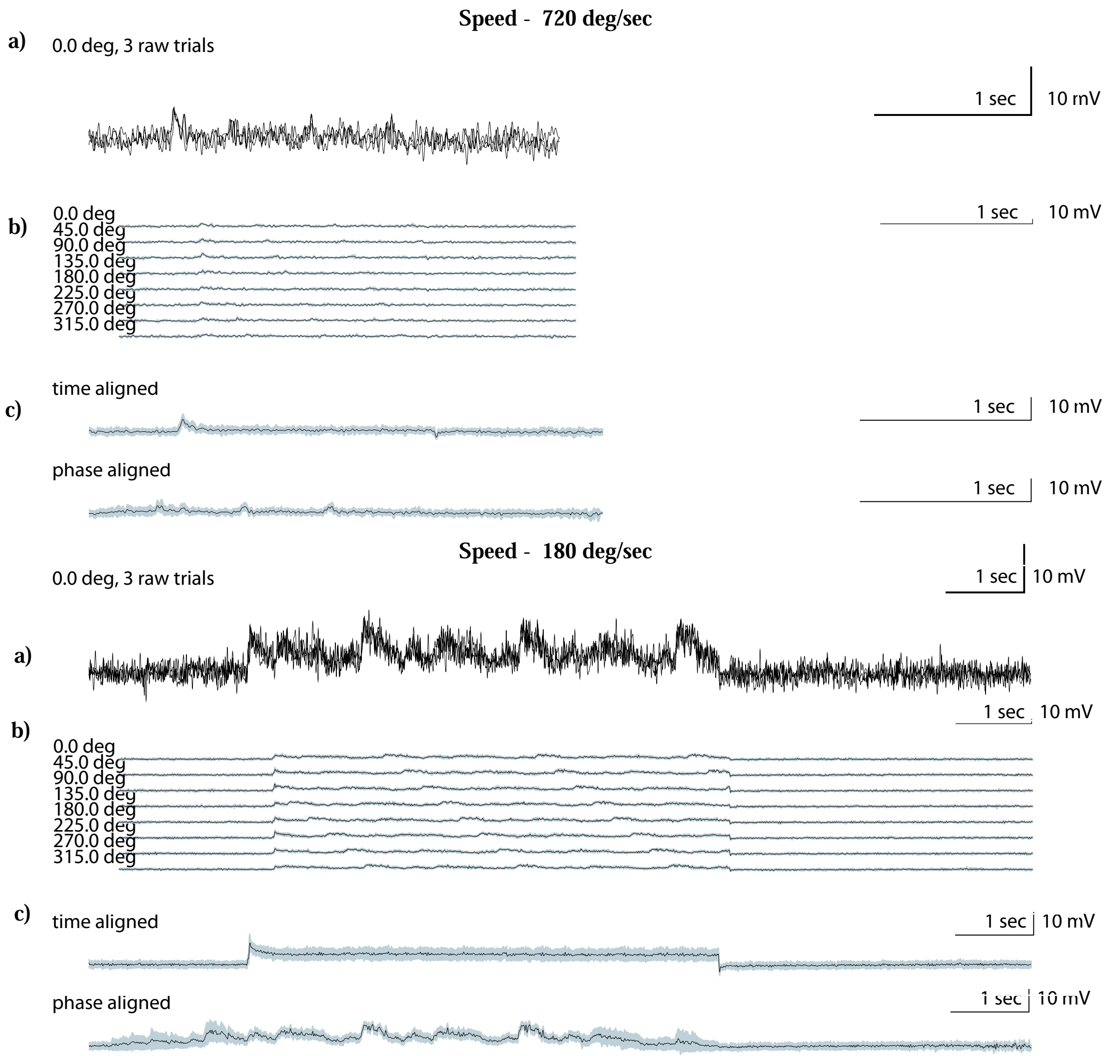

Figure 7.2. Pattern noise in fly response for images moving at high and low speeds at a low contrast of 0.2. This figure shows the effect of pattern noise on response of a single fly wide-field motion detecting neuron (HS cell) to a natural image (see Figure 7.1) with the image presented is moving at high speed of 720 degrees per second and low speed of 180 degrees per second at 8 different initial phases, each 45 degrees apart at a very low contrast of 0.2. For each combination of velocity and image, part (a) shows three responses to identical experimental conditions. Part (b) shows the mean of at least three responses at each of several stimulus positions. Part (c) show the mean response in black and the standard deviation of the response around the mean in gray. The responses were 'phase aligned' by compensating for the position change before averaging. The 'time aligned' response shows the individual responses at each initial position averaged without compensating for position change [Rajesh et al., 2005c]. Inspection of the individual responses and the phase aligned response indicates that pattern noise is more significant at low contrasts.

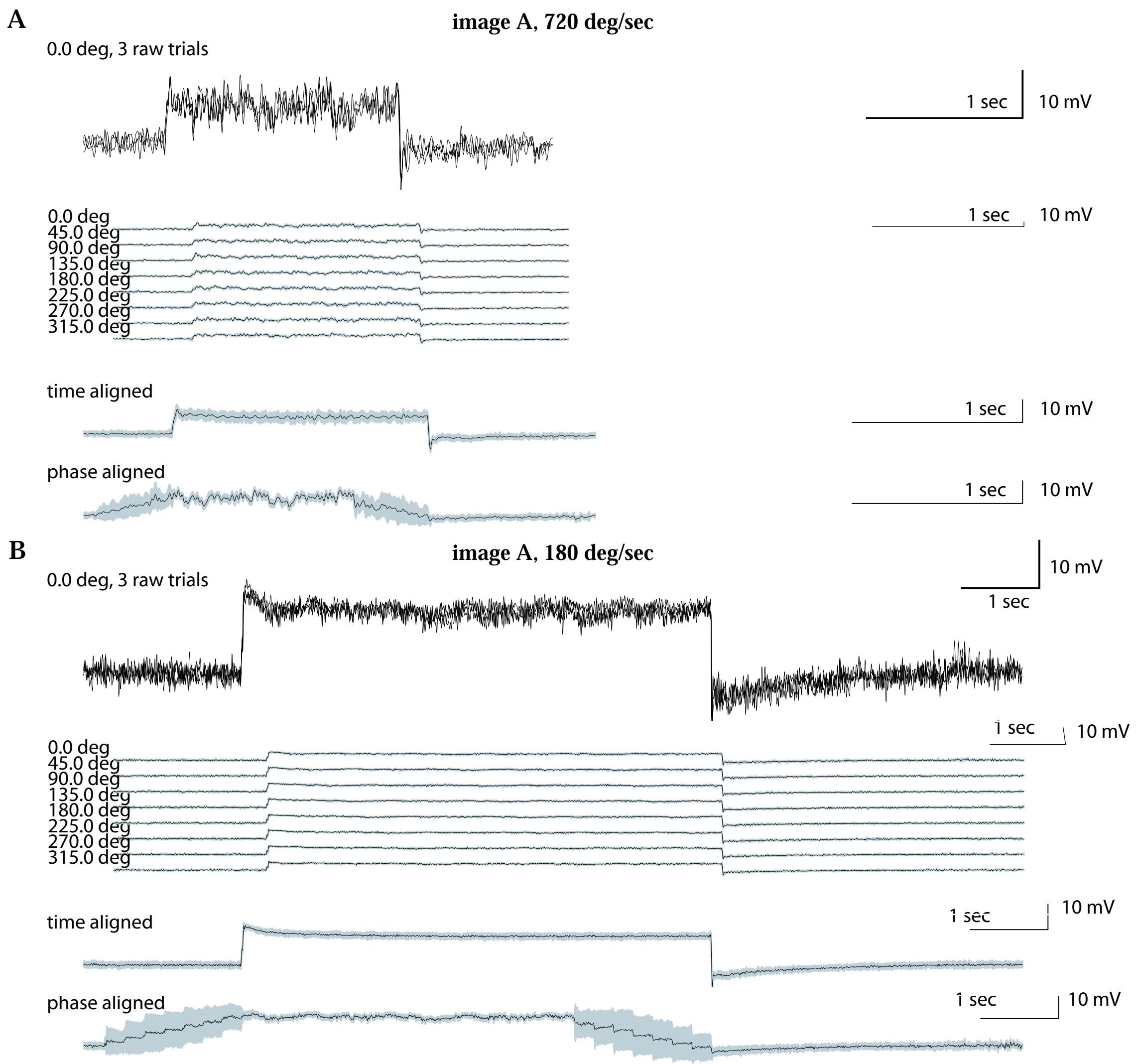

Figure 7.3. Pattern noise in fly response for images moving at high and low speeds at a high contrast of 1. This figure shows the effect of pattern noise on response of a single fly wide-field motion detecting neuron (HS cell) to a natural image (see Figure 7.1), with the image presented moving at high speed of 720 degrees per second and low speed of 180 degrees per second at 8 different initial phases, each 45 degrees apart at a high contrast of 1. For each combination of velocity and image, part (a) shows three responses to identical experimental conditions. Part (b) shows the mean of at least three responses at each of several stimulus positions. Part (c) show the mean response in black and the standard deviation of the response around the mean in gray. The responses were 'phase aligned' by compensating for the position change before averaging. The 'time aligned' response shows the individual responses at each initial position averaged without compensating for position change [Rajesh et al., 2005c]. Inspection of the individual responses and phase aligned responses indicates that pattern noise is more prominent at higher speeds.

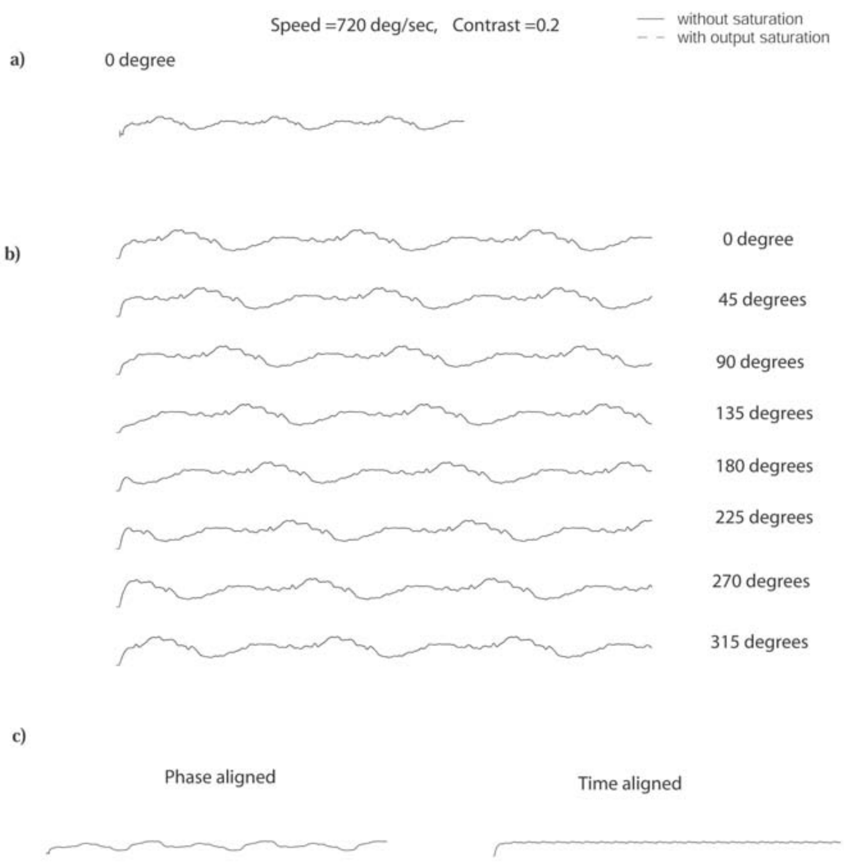

Figure 7.4. Pattern noise in simulation result for images at high speed at a low contrast of 0.2. This figure shows the simulation results obtained by running the model with and without implementing output saturation, at 720 degrees per sec at a low contrast of 0.2 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the results obtained with and without adding saturation shows, that addition of saturation has no effect at low contrasts as the response saturates only at higher contrasts.

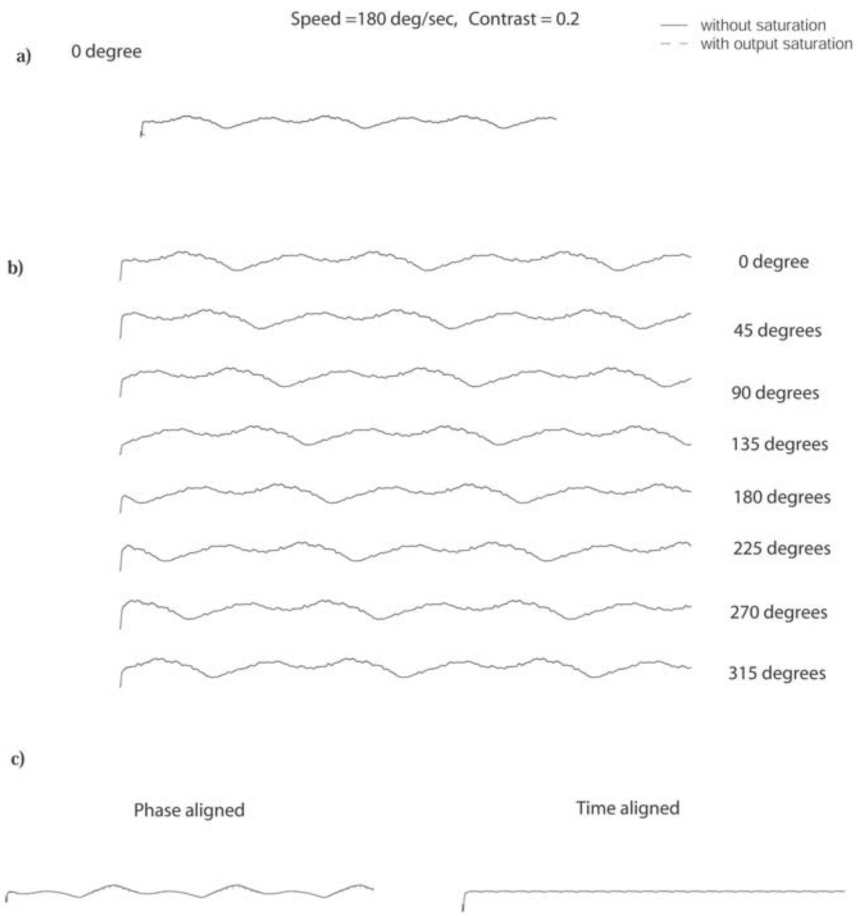

Figure 7.5. Pattern noise in simulation result for images at low speed at a low contrast of 0.2. This figure shows the simulation results obtained by running the model with and without implementing output saturation, at 180 degrees per sec at a low contrast of 0.2 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown in Figure 2. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the results obtained with and without adding saturation shows, that addition of saturation has no effect at low contrasts as the response saturates only at higher contrasts.

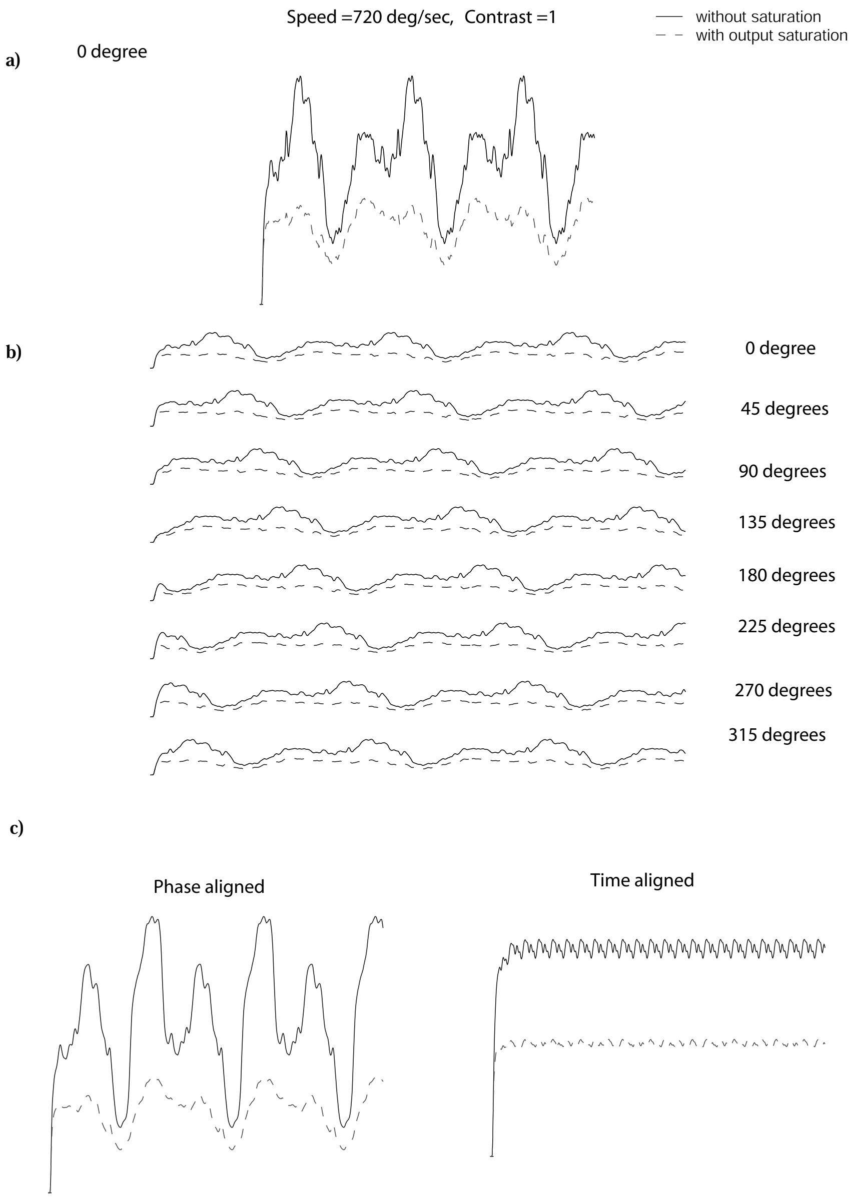

Figure 7.6. Pattern noise in simulation result for images at high speed at a high contrast of 1. This figure shows the simulation results obtained by running the model with and without implementing output saturation, at 720 degrees per sec at a high contrast of 1 using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the model with saturation and without saturation shows that saturation implemented at the out put affects the pattern noise at high contrast by reducing the magnitude of the response and changing the shape of the pattern noise as can be seen from the phase aligned response

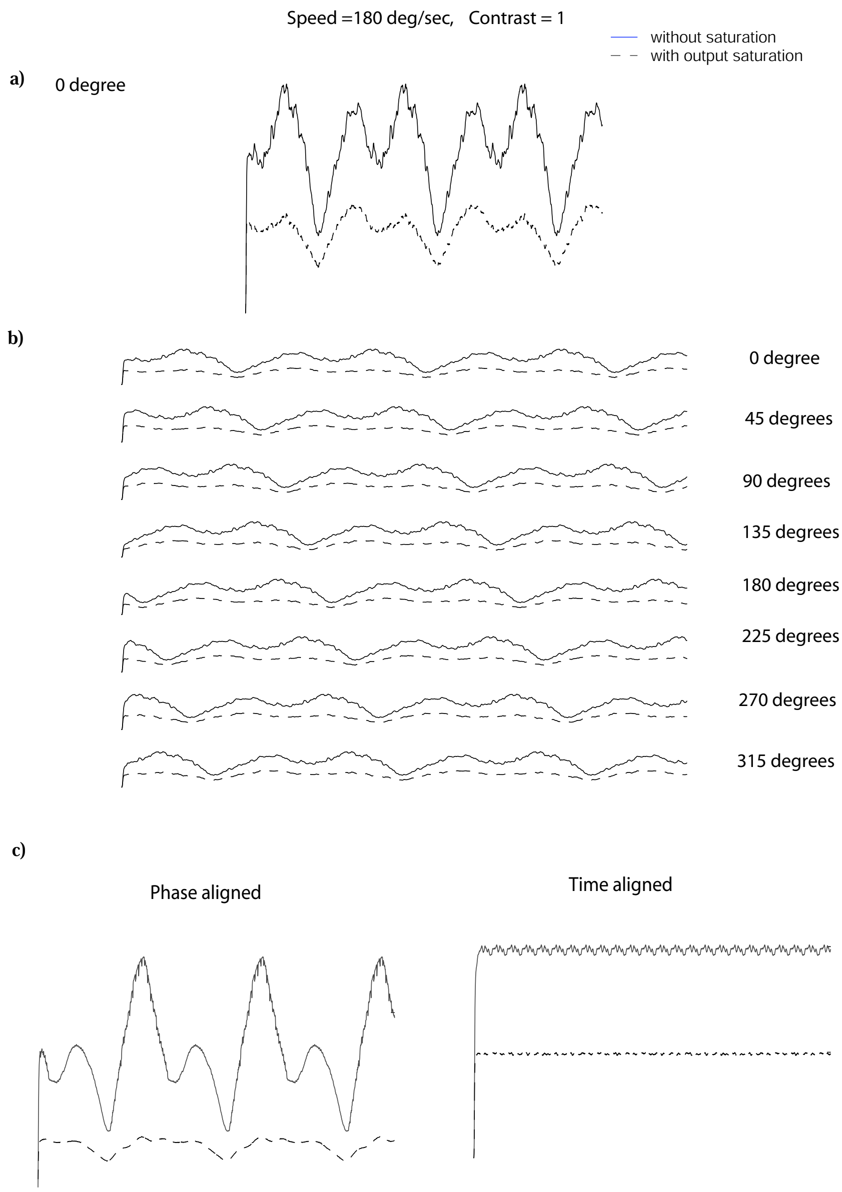

Figure 7.7. Pattern noise in simulation result for images at low speed at a high contrast of 1. This figure shows the simulation results obtained by running the model with and without implementing output saturation, at 180 degrees per sec at a high contrast of 1, using the same image, at 8 different initial phases, each 45 degrees apart, as done in the physiological experiment shown above. Part (a) of the graph shows the response with and without saturation at phase zero. Part (b) shows the response with and without saturation, to each of the 8 configurations. Part (c) shows the response with and without saturation, averaged in two ways, time aligned and phase aligned [Rajesh et al., 2005c]. Comparison of the model with saturation and without saturation shows that saturation implemented at the output affects the pattern noise at high contrast by reducing the magnitude of the response and changing the shape of the pattern noise as can be seen from the phase aligned response

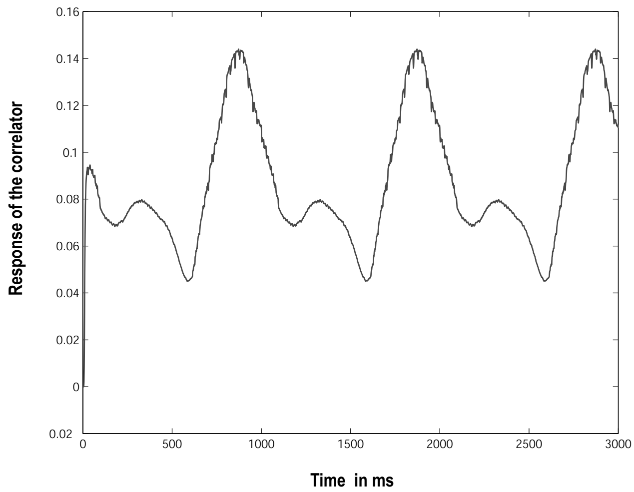

Figure 7.8. Simulated phase aligned results with saturation implemented only at the input. This figure shows the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. In the phase aligned method, each phase delayed response is aligned by shifting each response along the x-axis with the data obtained for phase zero and then it is averaged. In this case, saturation is implemented at the correlator input after the spatial filtering stage.

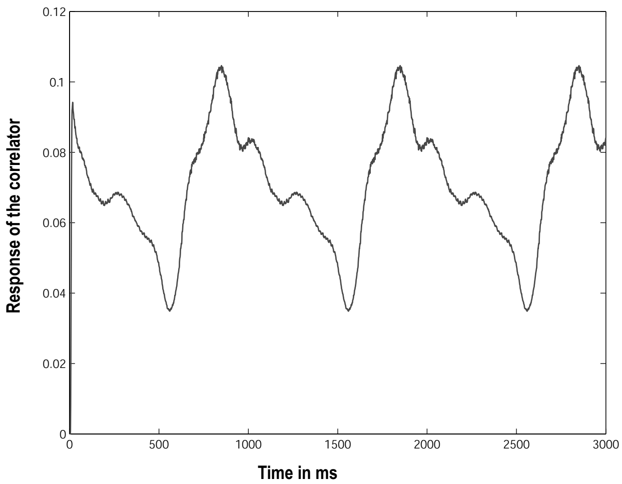

Figure 7.9. Simulated phase aligned results with saturation implemented only at the correlator arms. This figure shows the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. In the phase aligned method, each phase delayed response is aligned by shifting each response along the x-axis with the data obtained for phase zero and then it is averaged. The pattern noise present can be seen. In this case, saturation is implemented at the correlator arms at the multiplication stage. It is seen that the shape of the pattern noise is different from the previous case where saturation was implemented only at the input stage.

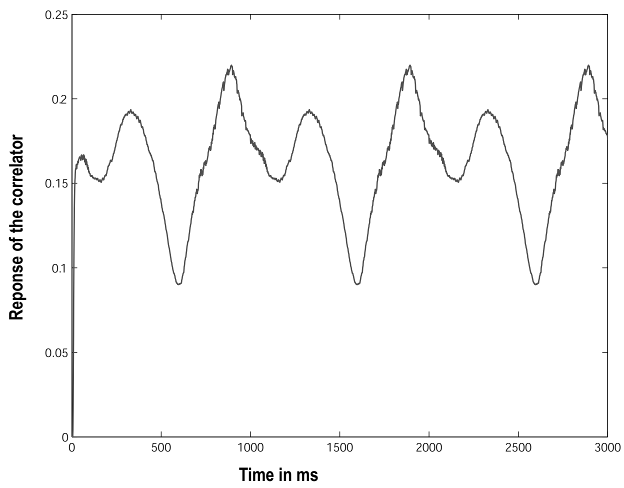

Figure 7.10. Simulated phase aligned result with saturation implemented only at the output. This figure shows the phase aligned simulation results obtained by running the model at 180 degrees per sec using the same image, at 8 different initial phases, each 45 degrees apart. In the phase aligned method, align each phase delayed response by shifting each response along the x-axis with the data obtained for phase zero and then we average it. The pattern noise present can be seen. In this case, saturation is implemented at the output stage on the average EMD response. Note that the shape of the pattern noise is different from the previous two cases.

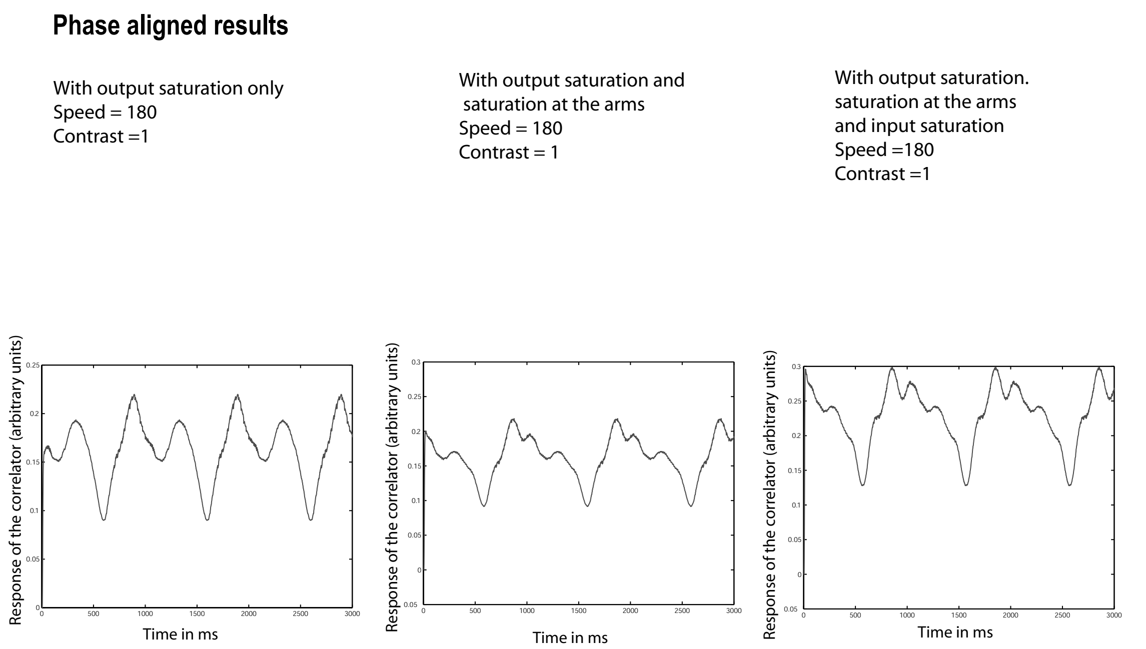

Figure 7.11. Comparison of simulated phase aligned results with saturation implemented at the input, arms and at the output. This figure shows the phase aligned simulation results obtained by running the model at 180 degrees per sec at contrast 1 using the same image, at 8 different initial phases, each 45 degrees apart. In the first case, saturation is implemented only at the output stage that is after the outputs of the EMDs are averaged. In the second case, saturation is implemented at the correlator arms before the multiplication stage along with output saturation. And in the third case, saturation is also present at the input, after spatial averaging, along with saturation at the arms and output saturation. It is seen that the shape of the pattern noise changes when saturation is implemented at more than one points with more bumps seen when more saturation is added. It is also noted that the position of saturation in the visual system of insect has an influence on pattern noise.

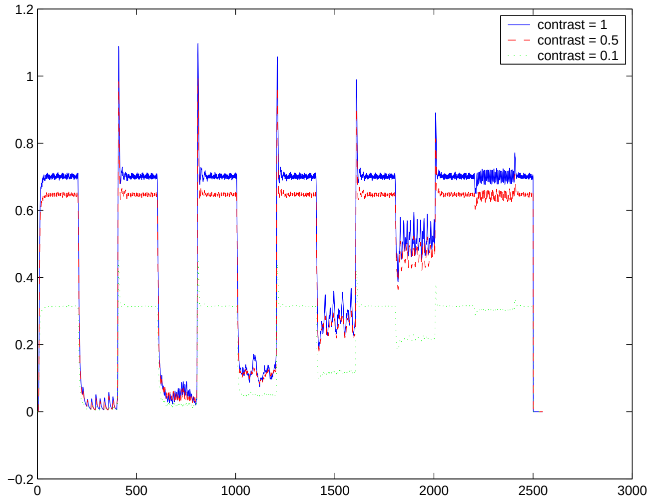

Figure 7.12. Simulated mean correlator response at three different contrasts with saturation implemented only at the input. This figure compares the simulated mean response of one row of EMDs of an elaborated model at three different contrasts (1, 0.5, 0.1) with saturation implemented only at the input. It is seen that the addition of compressive non-linearity squashes the response of the correlator, thereby reducing the variation of the response to contrast.

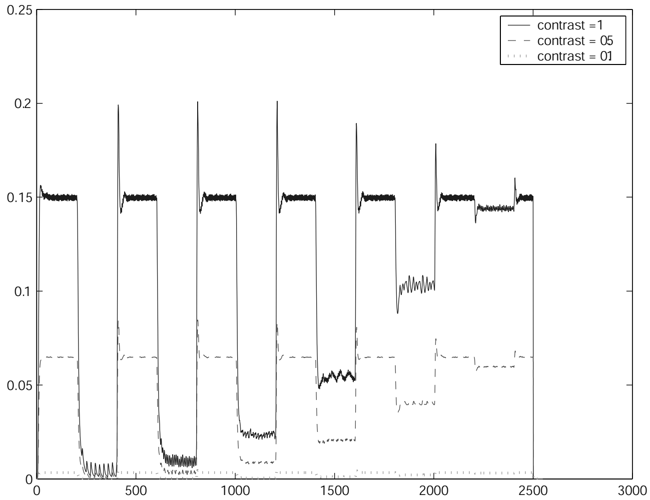

Figure 7.13. Simulated mean correlator response at three different contrasts with saturation implemented only at the correlator arms. This figure compares the simulated mean response of one row of EMDs of an elaborated model at three different contrasts (1, 0.5, 0.1) with saturation implemented only at the correlator arms. It is seen that the addition of compressive non-linearity only at the arms has a remarkable effect on reducing the contrast variations. Saturation implemented at the correlator arms causes more squashing of the response there by decreasing the dependance of the response to contrast further.

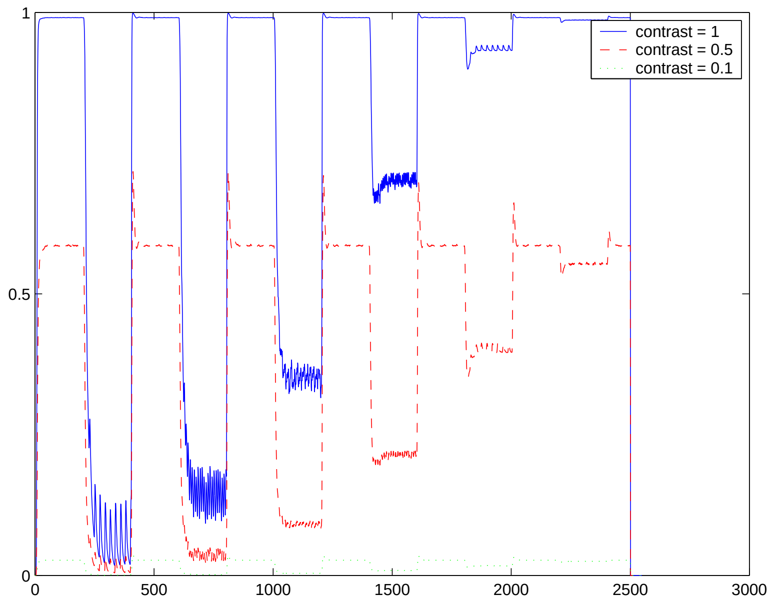

Figure 7.14. Simulated mean correlator response at three different contrasts with saturation implemented only at the output. This figure compares the simulated mean response of one row of EMDs of an elaborated model at three different contrasts (1, 0.5, 0.1) with saturation implemented only at the output on the mean EMD response. It is seen that the addition of compressive non-linearity at the output alone has less affect on reducing the contrast variation when compared to the implementation of saturation at the correlator arms. So though saturation at the output reduces the dependance of the response to contrast it has less affect than saturation implemented only at the arms.

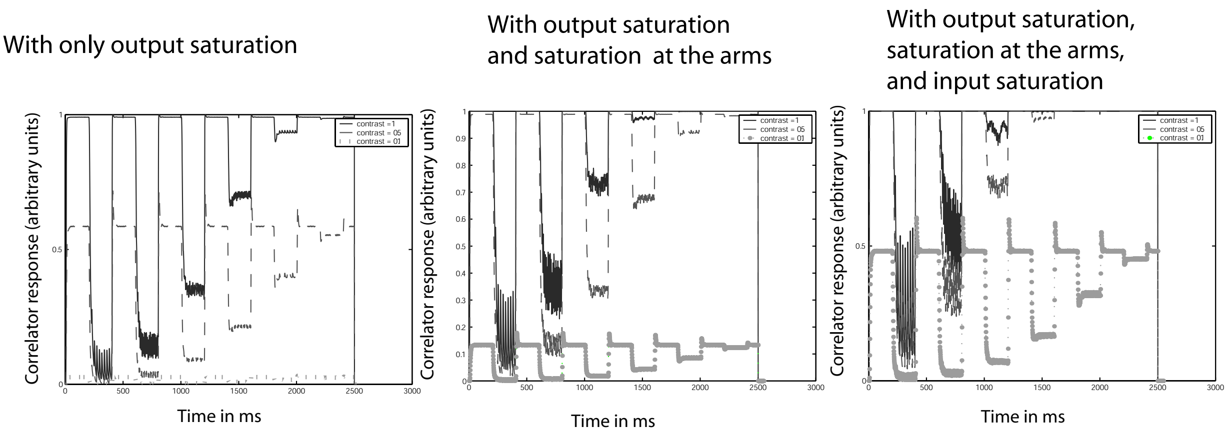

Figure 7.15. Simulated mean correlator response at three different contrasts with saturation implemented at more than one point in the model. This figure compares the simulated mean response of one row of EMDs of an elaborated model at three different contrasts (1, 0.5, 0.1) with saturation implemented in the first case, only at the output on the mean EMD response. In the second case, saturation is implemented at the output and at the correlator arms and in the third case, saturation is implemented at the output, at the correlator arms and also at the input. It is seen that the addition of compressive non-linearity squashes the response of the correlator. It is seen that the when the compressive non-linearity is added only at the output, the variation of the response is huge with the lowest contrast giving very low response and the highest contrast giving a very high response. But addition of saturation at the arms decreases the variation of the response to contrast and the further addition of saturation at the input further reduces the effect of contrast on the correlator response suggesting saturation could have a key role in reducing the contrast dependance in fly motion pathway thereby helping them to signal velocity accurately.