Supplementary Figure S2. Schematic diagram of beat cancellation and the phase relationship of different neurons

The electric fish, *A. leptorhynchus*, is illustrated from a dorsal aspect together with a global sinusoidal input (5 Hz)- the zero crossing of this input is indicated with a dashed line. Such input might arise from tail bending or during conspecific interactions of fish with similar EOD frequencies. The input is typically 180° out of phase on the two sides of the body (Kelly et al., 2008). A superficial pyramidal cell (S) responds to low frequency input with a burst of spikes- for illustrative purposes this burst is shown as occurring precisely at the positive peak of the stimulus. For a 5 Hz frequency input a 4 spike burst is expected (as illustrated).

Deep pyramidal neurons on both sides of the body respond with tonic firing to the peak (E-cells) or trough (I- cells) of the stimulus (Bastian and Nguyenkim, 2001; Bastian et al., 2004; Marsat et al., 2009) ; the timing of this discharge (for both sides of the body) is illustrated. This paper has shown that parallel fiber burst input occurring up to 50 ms after a superficial pyramidal cell 4 spike burst can induce LTD specific to the stimulated fibers (right red line). As shown in Figure S1, the minimal delay of deep cell feedback to superficial pyramidal cells (via parallel fibers) is ~20 ms. Therefore deep cell discharge occurring 30 ms after an superficial E-cell burst can still reach its apical dendrites within the 50 ms LTD limit and cause depression. As illustrated (purple line) the discharge of ipsilateral deep E-cells and contralateral deep I-cells have the appropriate timing to induce LTD and therefore engage the cancellation mechanism.

This paper has also shown that parallel fiber burst input occurring 50 ms before a superficial pyramidal cell 4 spike burst can induce LTD specific to the stimulated fibers

(left red line). The maximal delay of deep cell feedback to pyramidal cells is ~70 ms. The purple line is therefore extended for 70 ms before the parallel fiber burst input. As illustrated the discharge of ipsilateral deep I-cells and contralateral deep E-cells have the appropriate timing to induce LTD and therefore engage the cancellation mechanism.

The purple line therefore represents the near maximal temporal extent of deep cell activity that is capable of inducing LTD in the illustrated pyramidal cell. Since deep E cells fire throughout the crest of the stimulus regardless of its frequency, and deep I cells fire throughout the trough (Bastian and Nguyenkim, 2001; Bastian et al., 2004; Marsat et al., 2009), deep cells from each side of the fish can provide a near continuous input to the EGp throughout all phases of any stimulus frequency. Assuming some heterogeneities or noise in the granule population, this varied deep cell input will translate into a distribution of granule cell burst delays as granule cells may selectively burst at any time during deep cell activity. Thus superficial pyramidal cells therefore receive multiple temporally overlapping feedback input that can contribute to a smooth cancellation of spatially redundant low frequency input.

Two additional points are evident from this figure. First, for a different frequency signal the phase of the feedback input would be altered (the delays are determined by anatomy and are therefore constant for any particular parallel fiber) and therefore become inappropriate for cancellation. This makes clear why the feedback input for cancellation must be frequency tuned. Second, this figure also makes it clear why a ±50 ms time window for plasticity would not work for higher frequencies. As shown in the figure (red lines) the time windows for plasticity are matched to the duration of the peak of the 5 Hz signal. In contrast, for a 10 Hz signal feedback input arriving at the trough of the beat would also be depressed (occur within 50 ms of the superficial E-cell burst). The resulting LTD of the feedback would prevent cancellation of the trough of the beat.

There are two untested assumptions associated with this diagram: (i) it is assumed here that E and I type responses of ELL pyramidal cells remain segregated in EGp granule cells and (ii) E and I type parallel fibers each contact both E and I type pyramidal cells. These assumptions will have to be verified to justify more detailed models of negative image formation by delayed feedback.

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