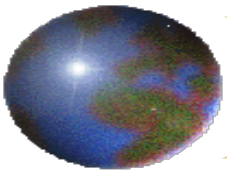


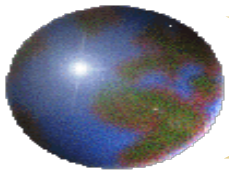
# Timing Recovery Algorithm Options for Modems with Rectangle Shaped Filters

*fred harris, Richard Bell, Vamsi Krishna*

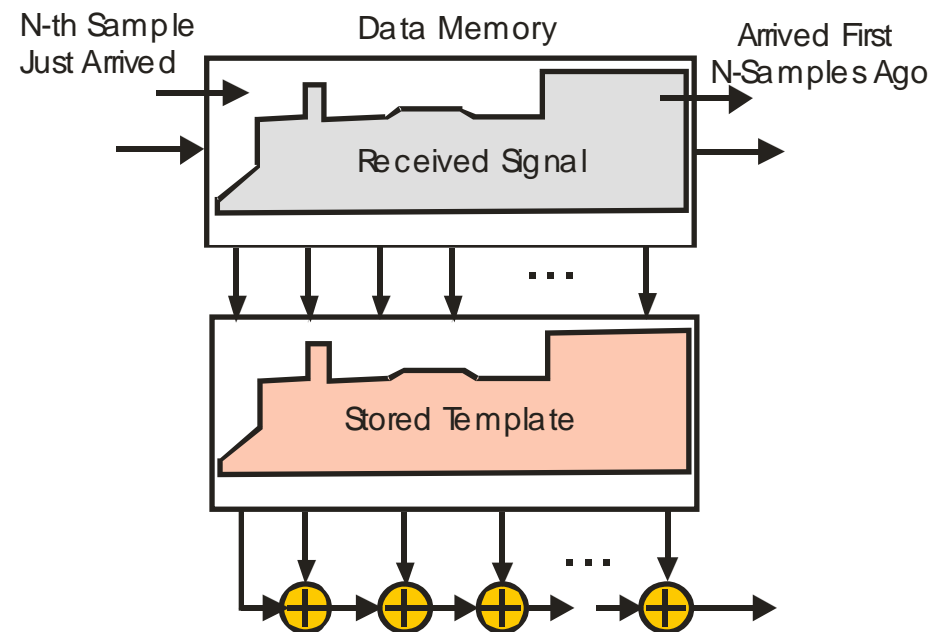
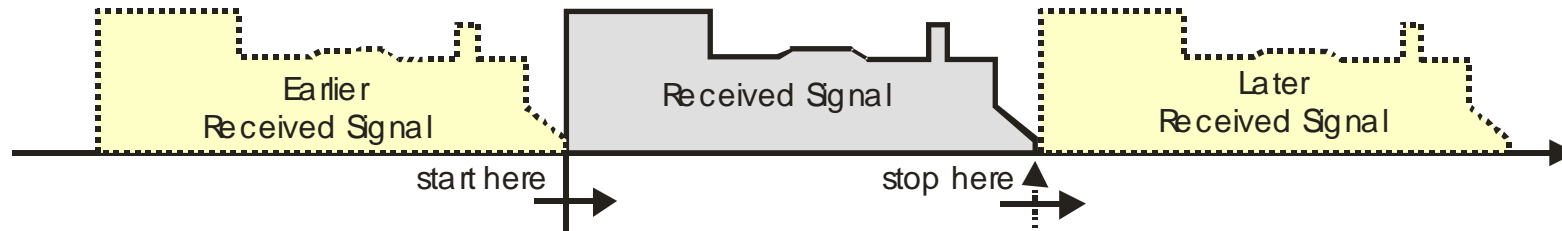


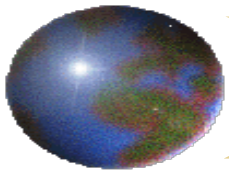
## *A Common Line in Adventure Movies!*



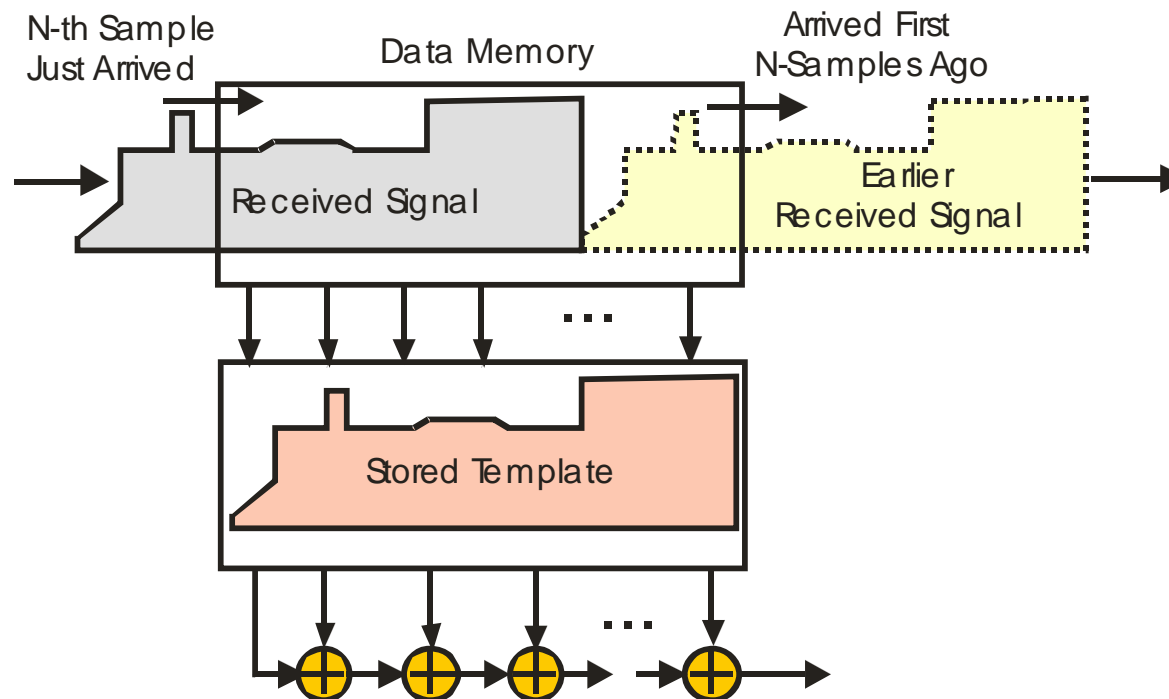
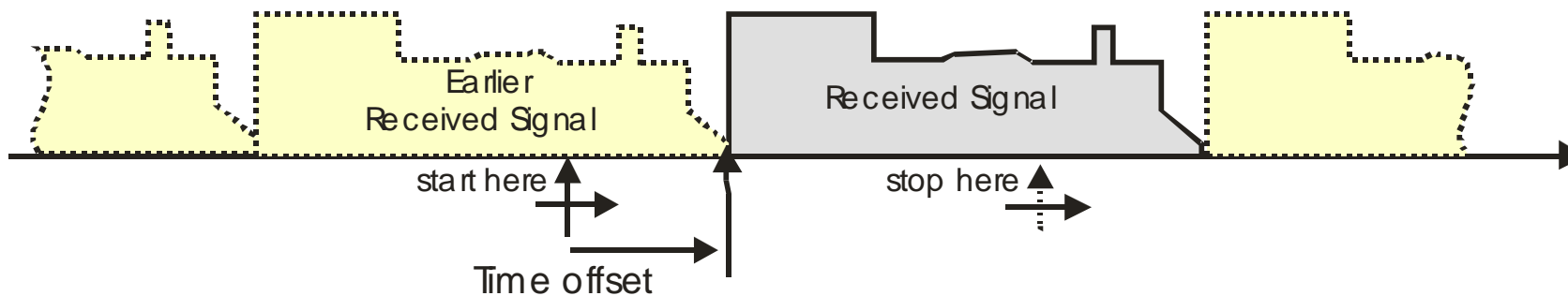


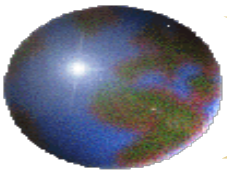
# Matched Filter Time Span Aligned with Received Input Time Span Boundaries



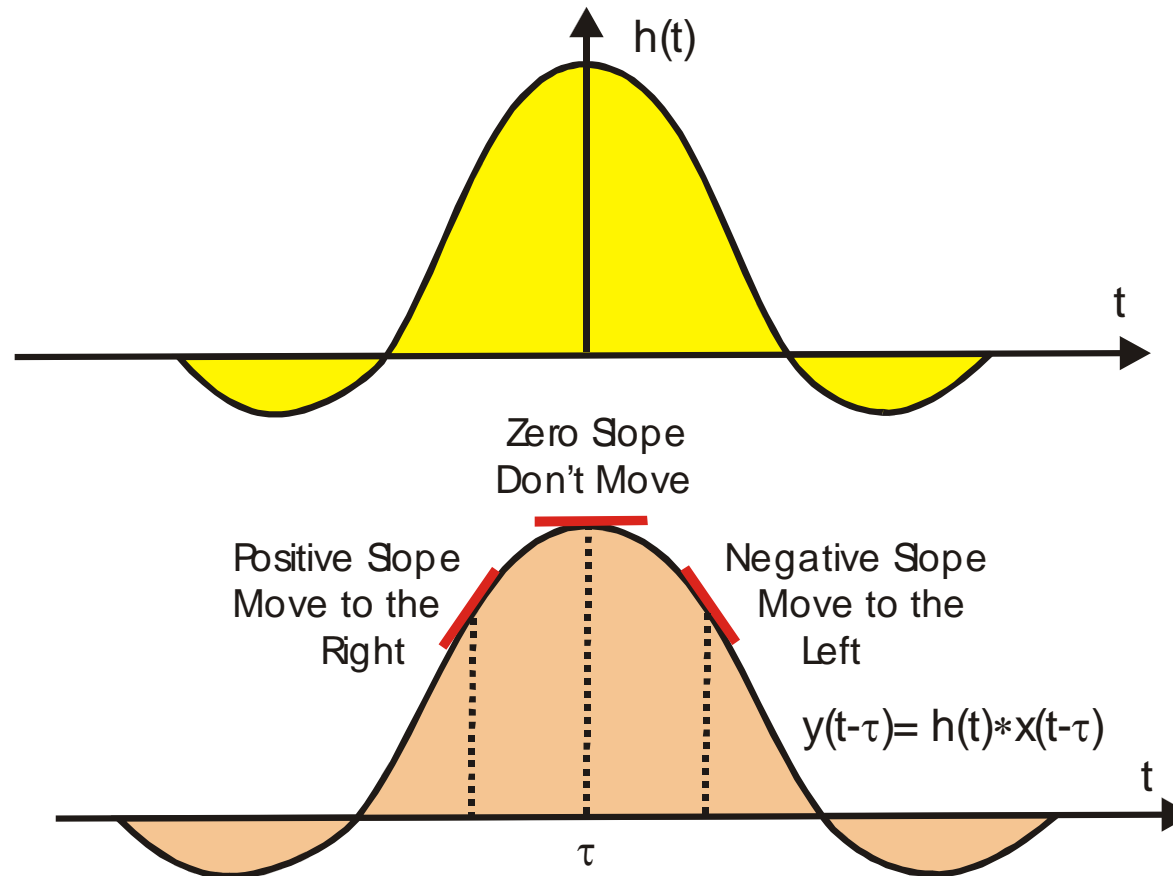


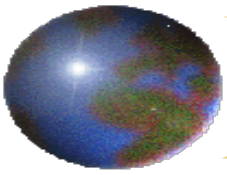
# Matched Filter Time Span Not Aligned with Input Time Span Boundaries



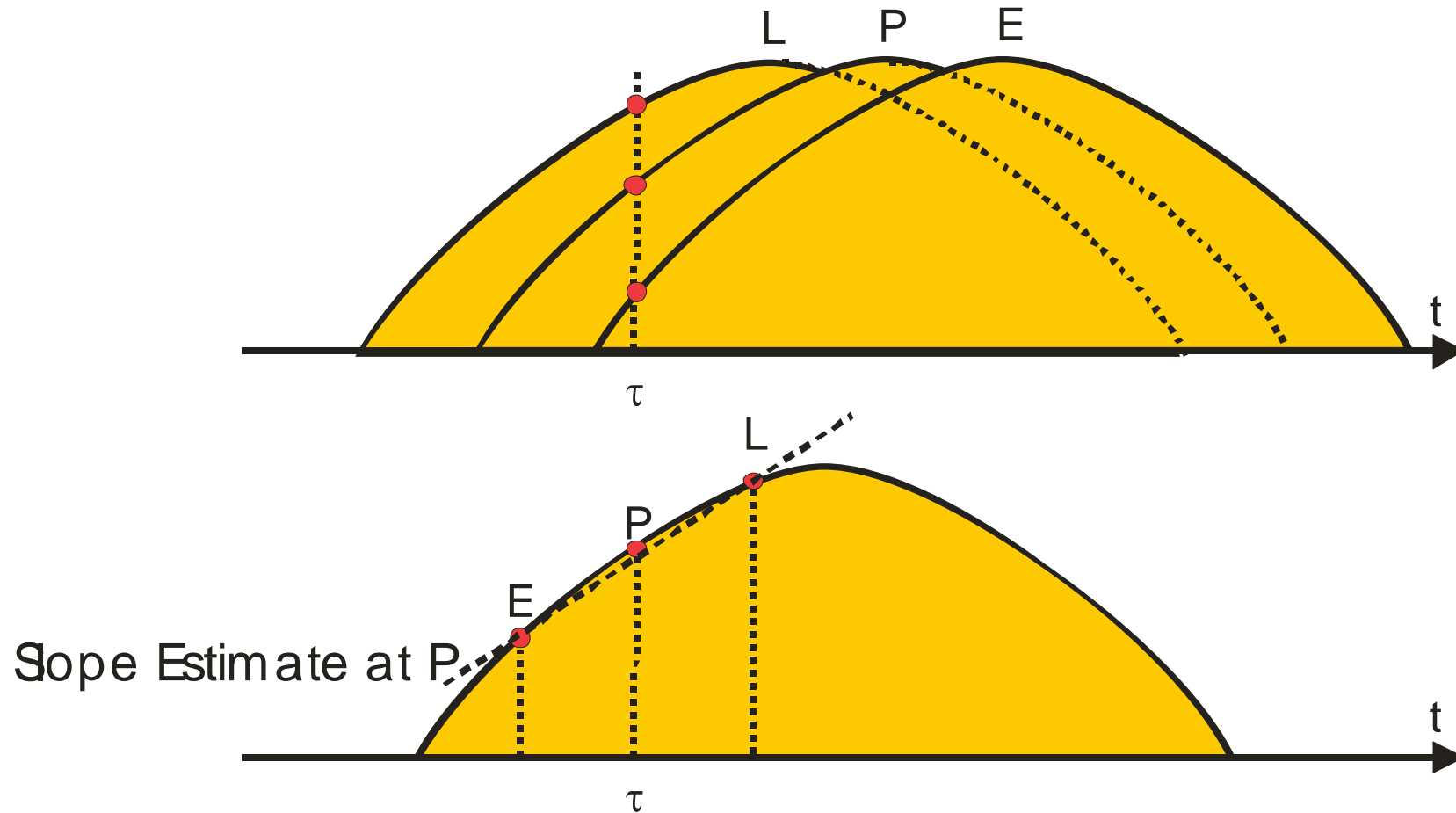


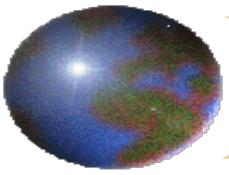
Correlator or Matched Filter Output for a Range of Time Offsets  
Alignment Corresponds to Correlation Peak. Peak Has Zero Slope.





# Observables from Early, Prompt, and Late Correlators Form Terms Required to Acquire Desired Time Alignment

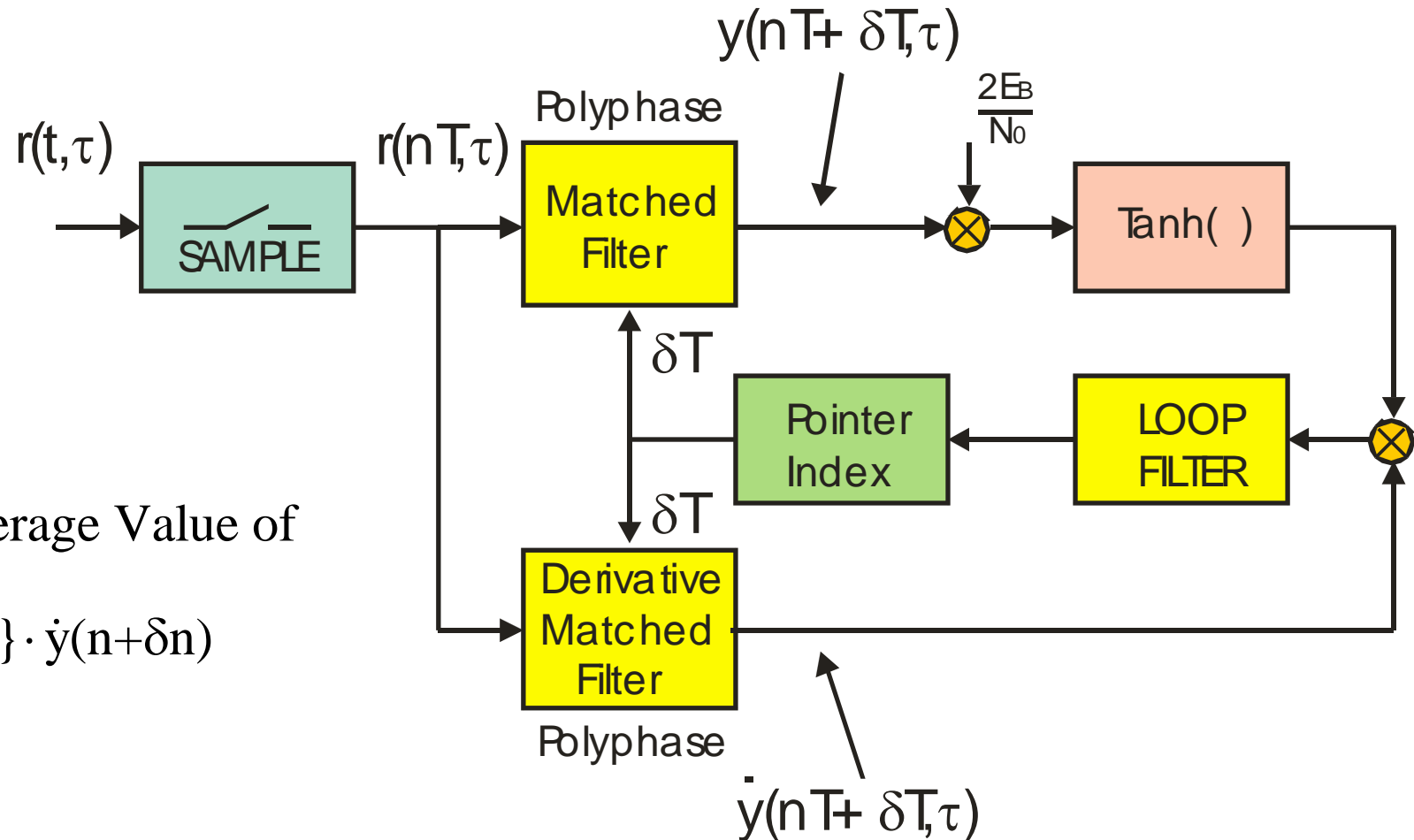


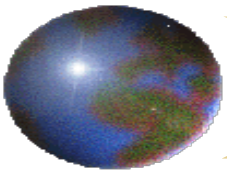


# Maximum Likelihood Timing Recovery Process:

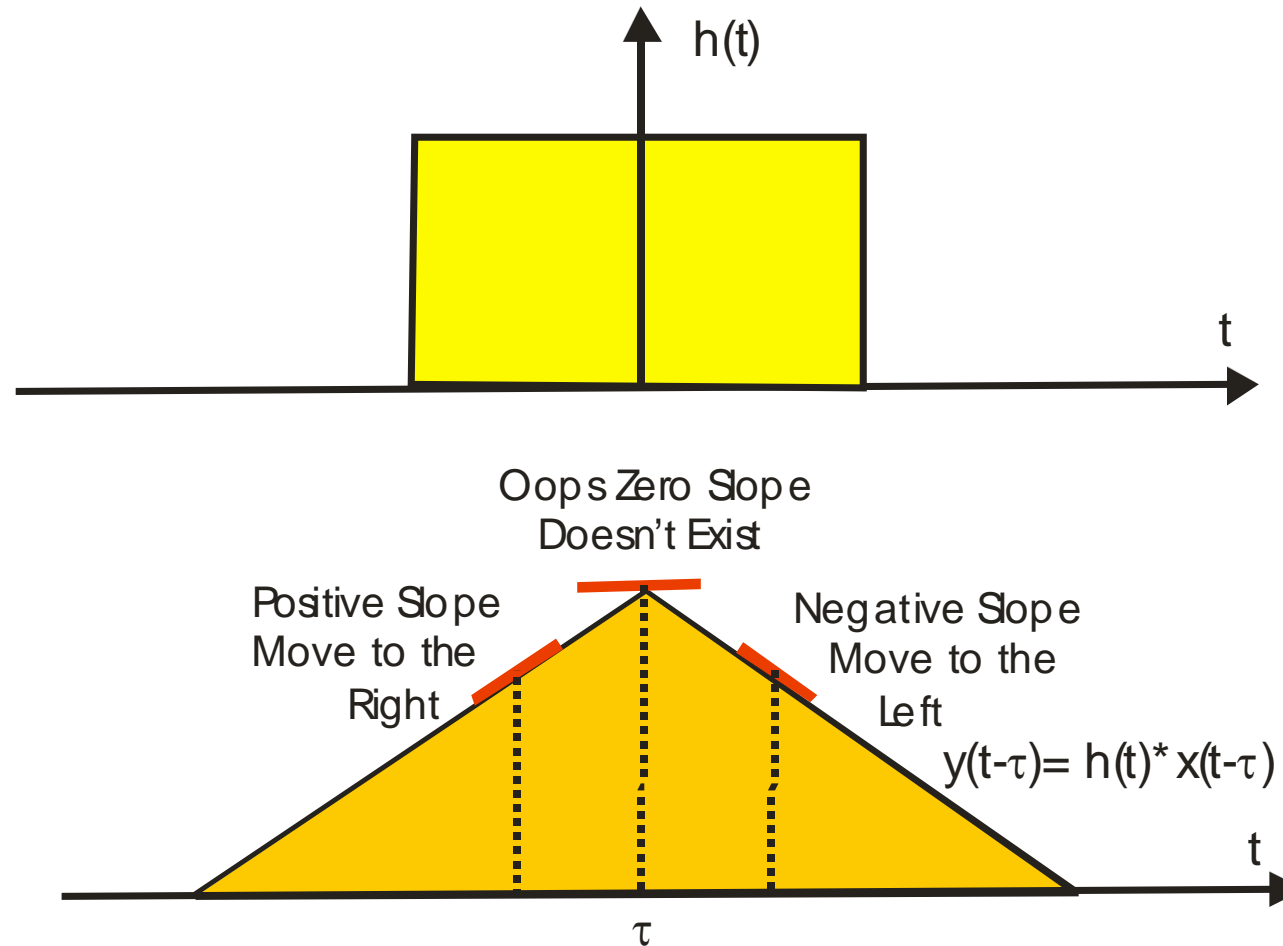
Drive to Zero the Average Value of

$$\text{Tanh}\left\{\frac{2E_b}{N_0} y(n+\delta n)\right\} \cdot \dot{y}(n+\delta n)$$

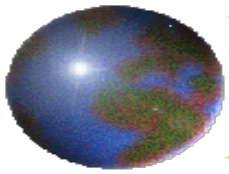




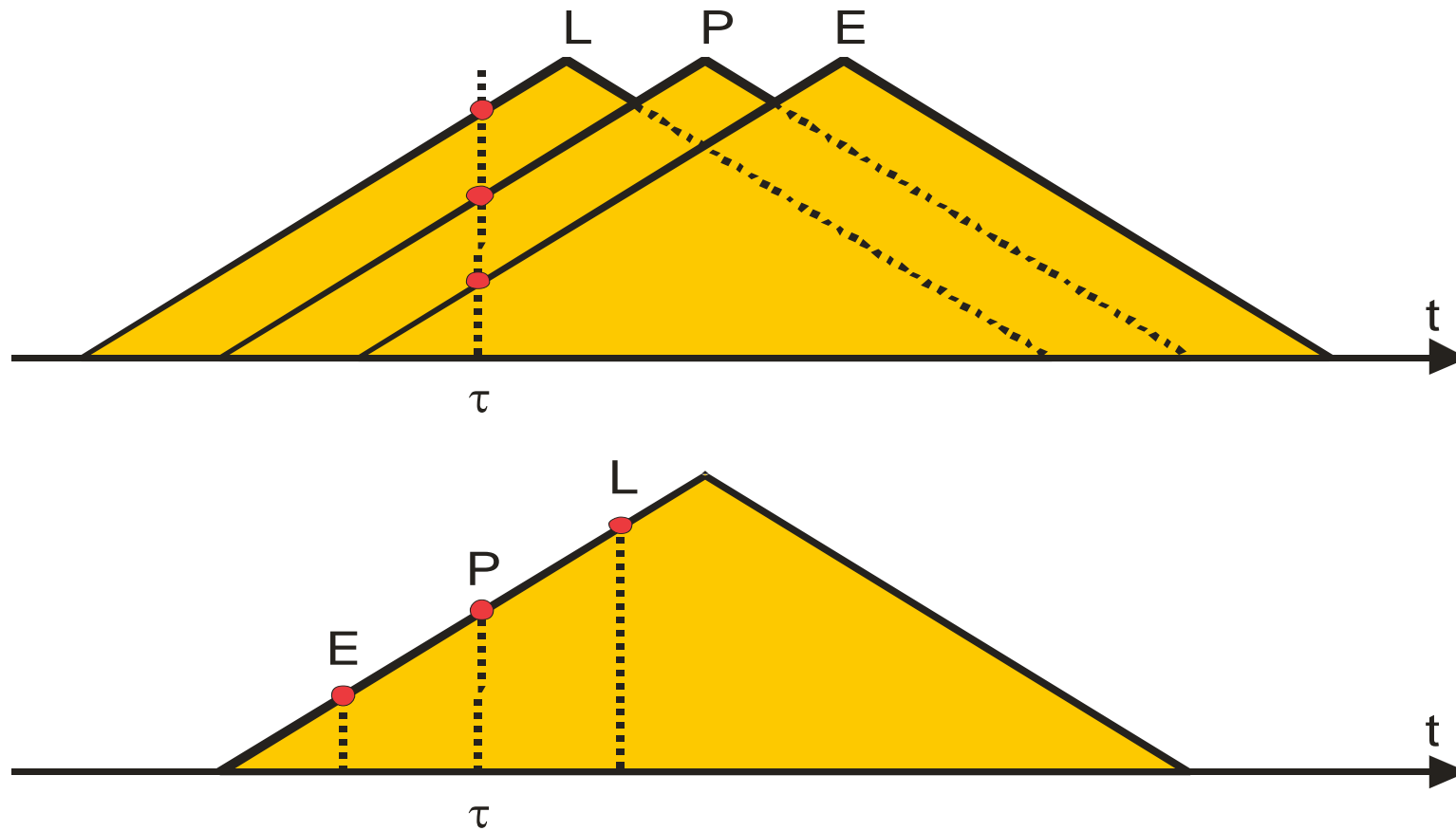
## Rectangle Shaping Filter Impulse Response and Matched Filter Response

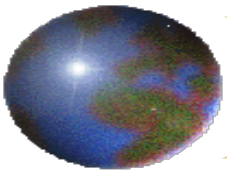




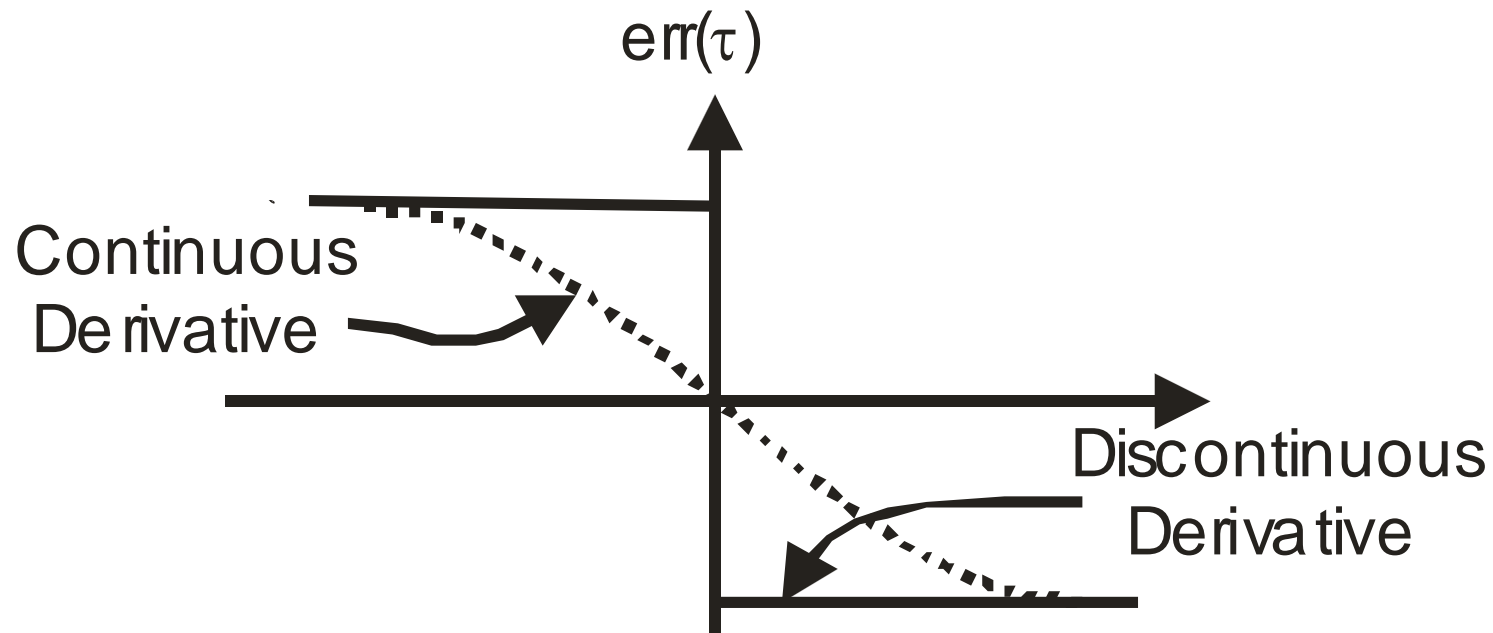


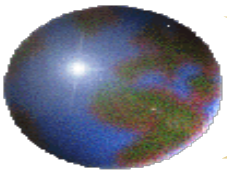
## Early, Prompt, and Late Correlators for Rectangle Shape Signaling Pulse





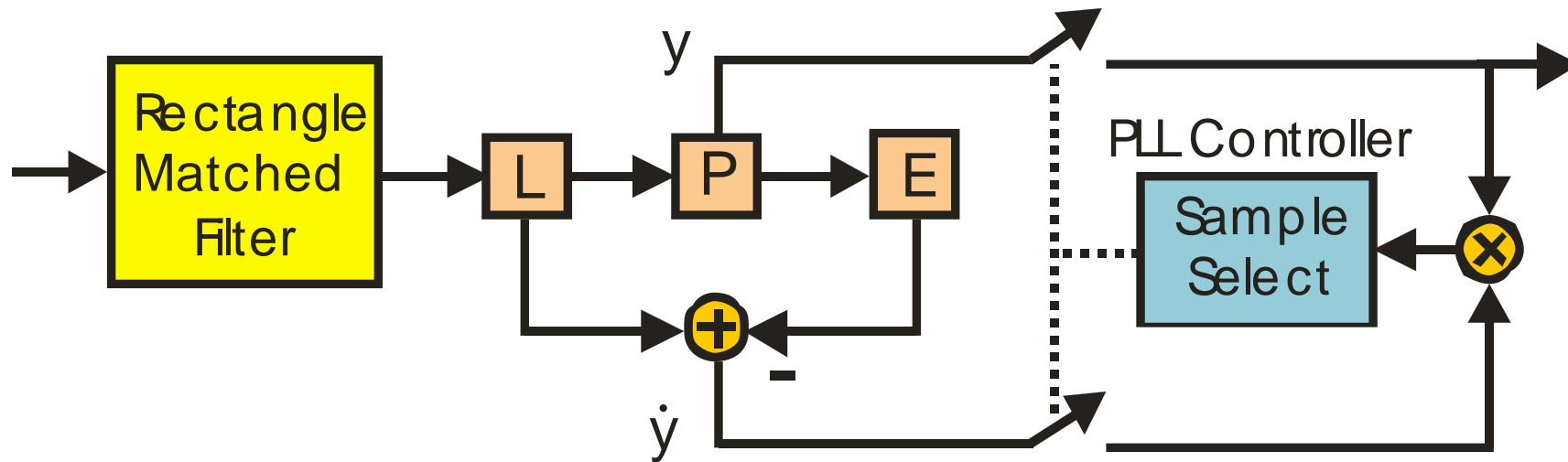
S-Curve Error Function in Neighborhood of Peak is Discontinuous  
Small Changes in Time Offset Cause Large Changes in Output  
Very Sensitive to Additive Noise

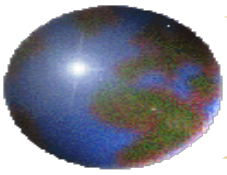




## Early-Prompt-Late Gates Formed From Three Successive Samples Output From Rectangle Matched Filter

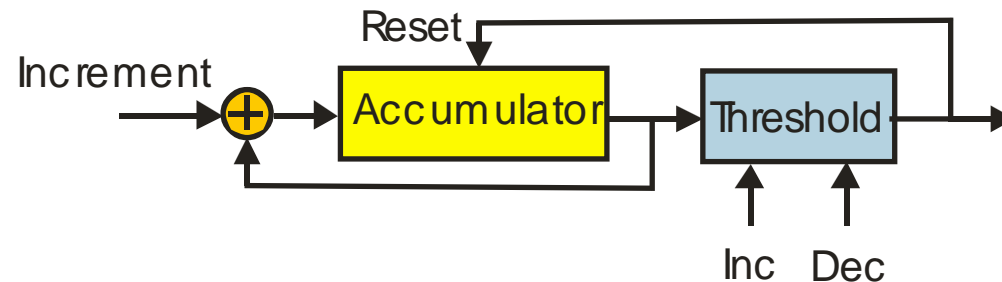
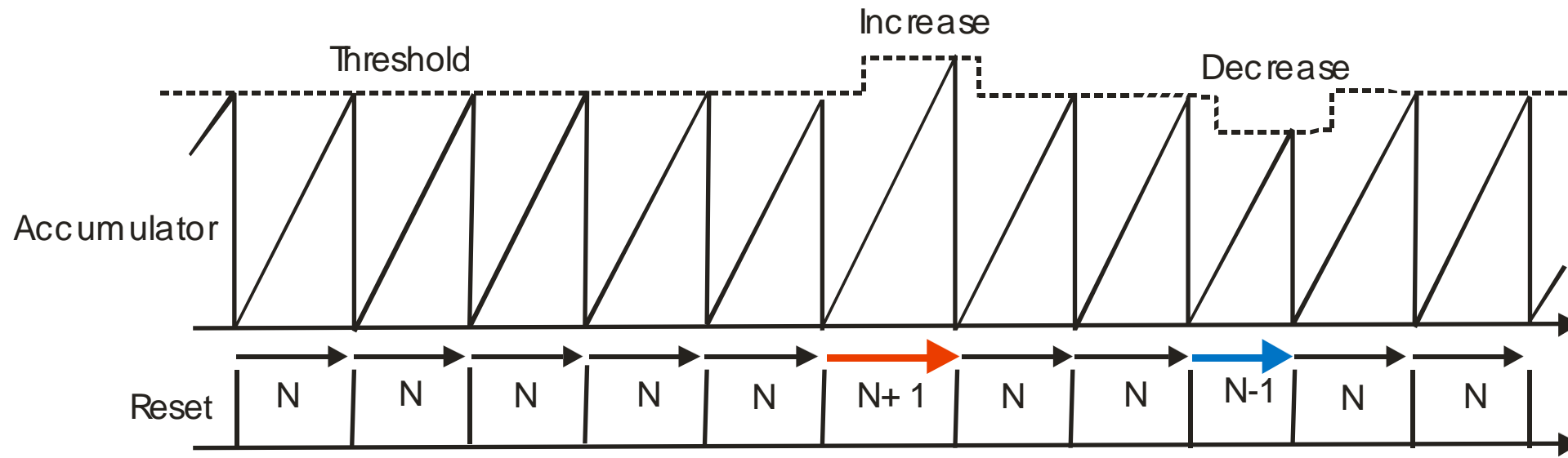
Timing Counter: Nominal  $N$  Samples per Symbol,  
Sample Select Shifts Timing Sample Left by Sampling Output at Count  $N-1$ ,  
and Shifts Timing Sample Right by Sampling Output at Count  $N+1$ ;

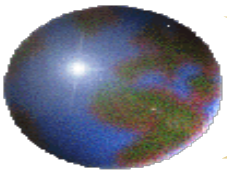




## Time Interval for Accumulator Reset

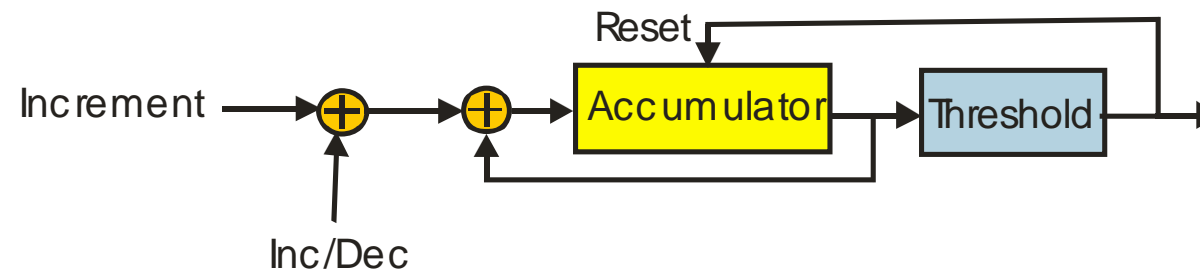
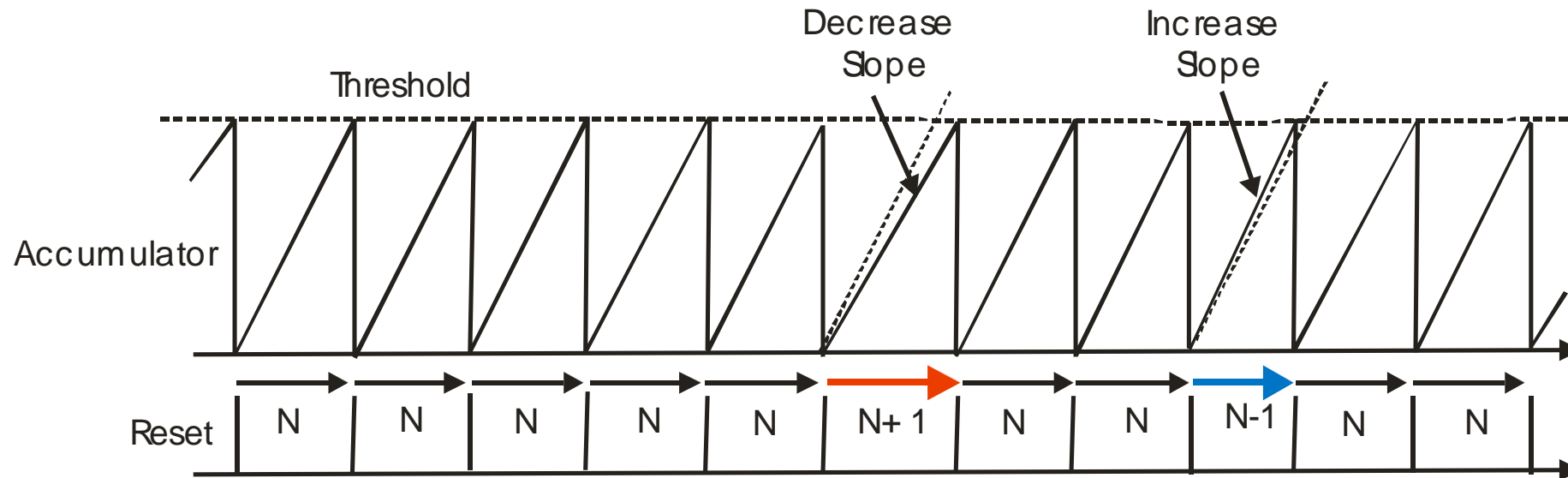
Can be Increased (Raise Threshold) to Shift Alignment to Right or  
Can be Decreased (Lower Threshold) to Shift Alignment to Left

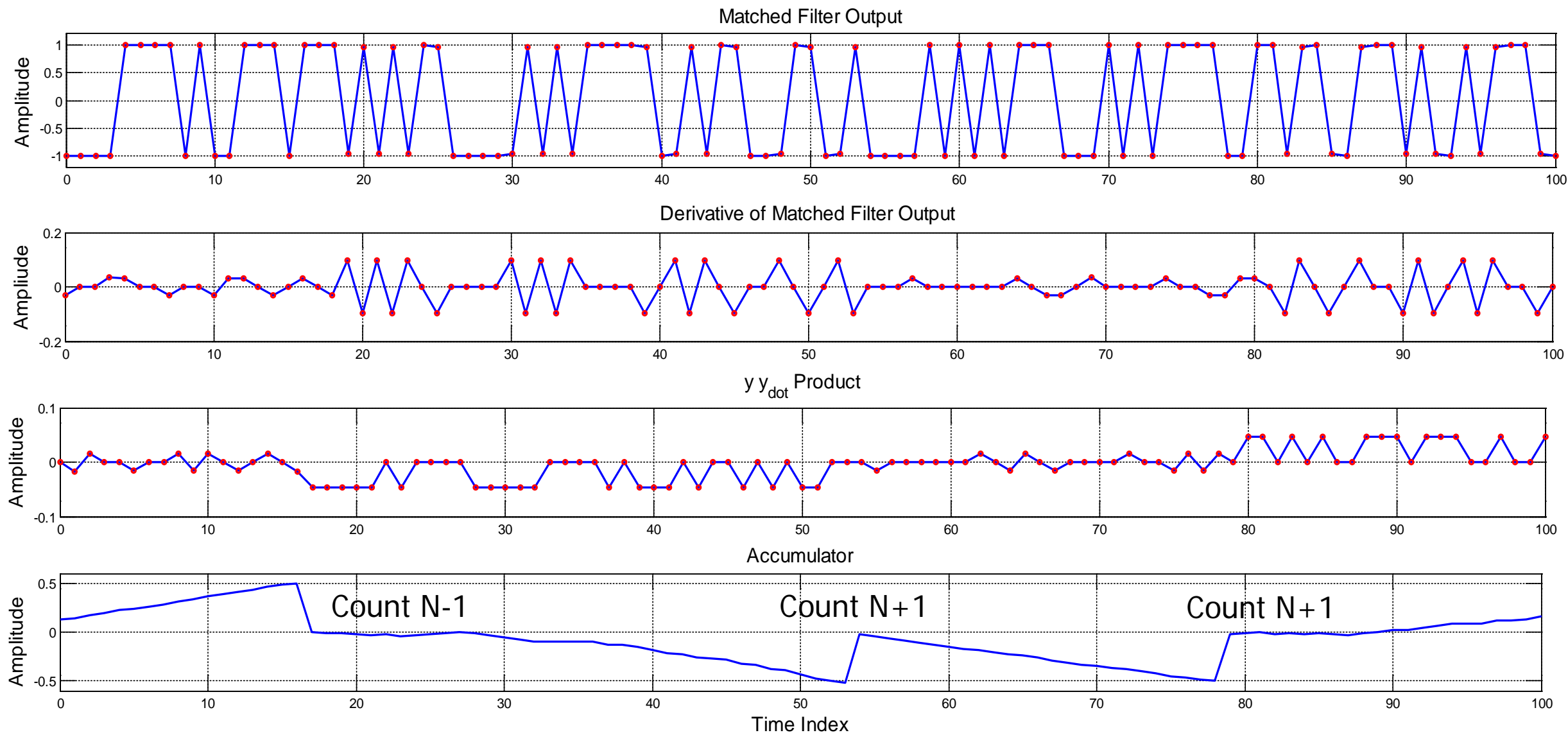
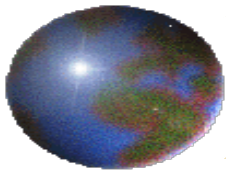


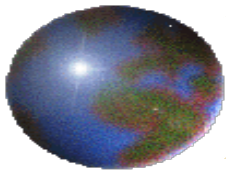


## Time Interval for Accumulator Reset

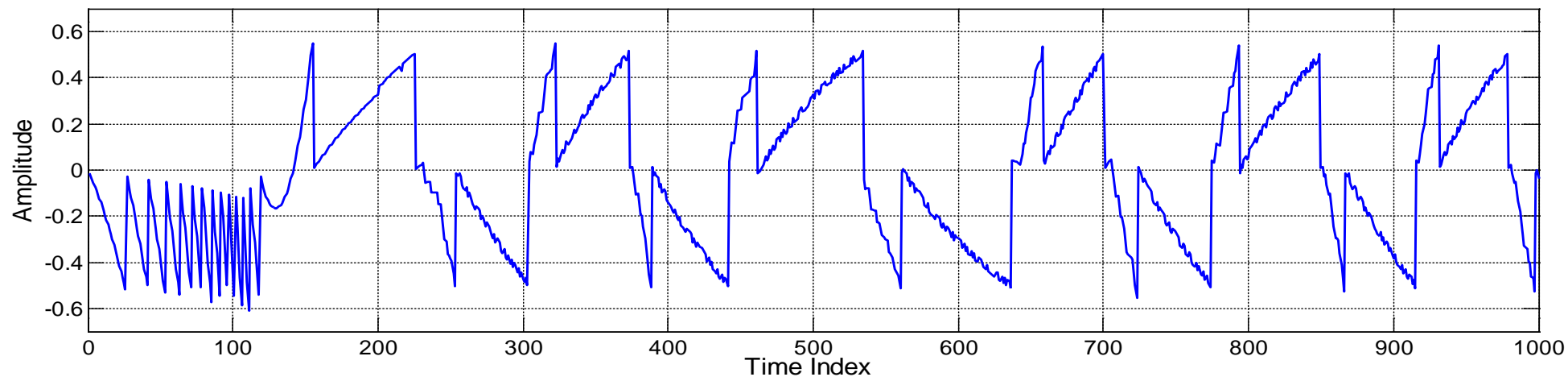
Can be Increased (Reduce Slope) to Shift Alignment to Right or  
Can be Decreased (Increase Slope) to Shift Alignment to Left



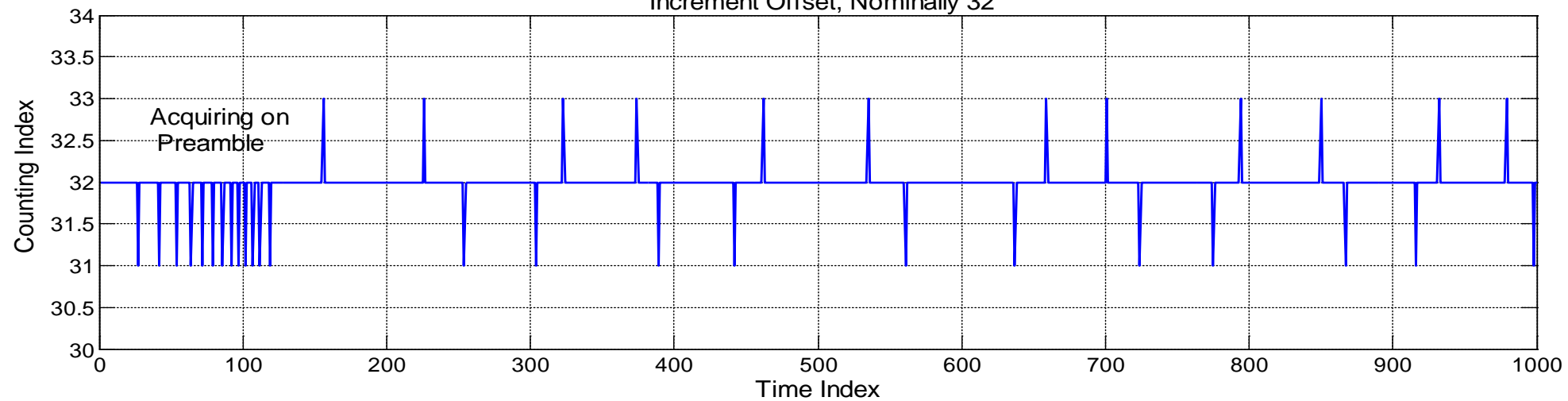


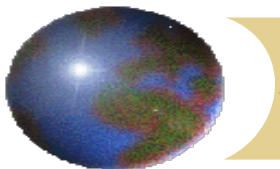


Output of Accumulator Offset From Increment 32: Increases when  $y_{\text{DOT}}$  is Positive, Decreases When  $y_{\text{DOT}}$  is Negative

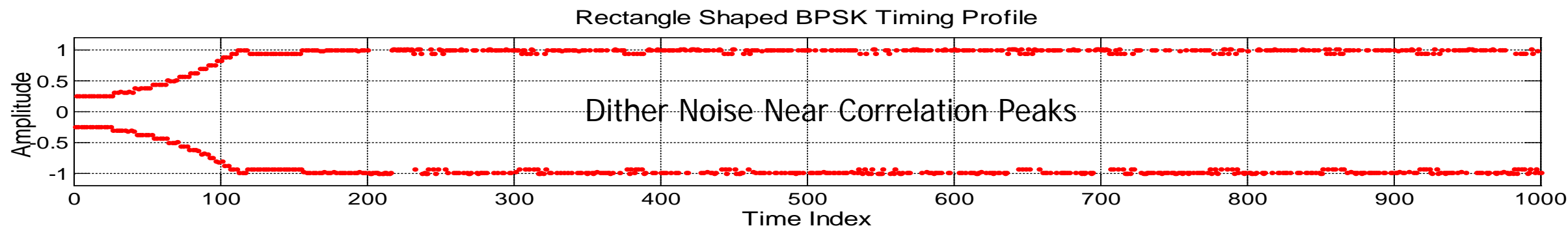
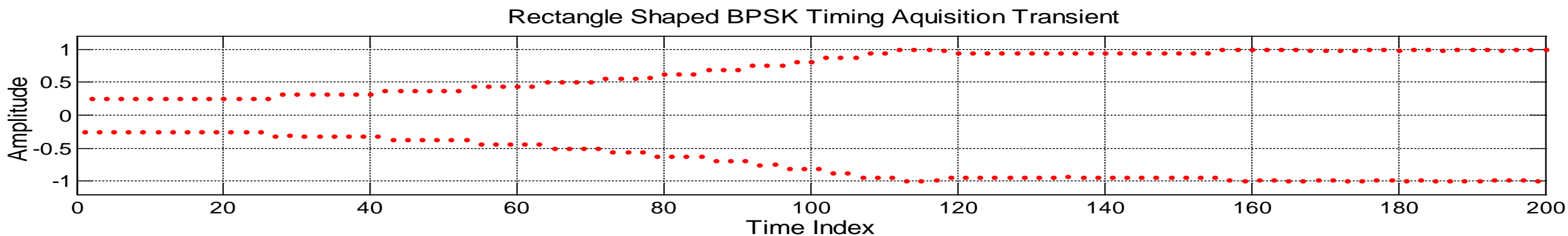


Increment Offset, Nominally 32

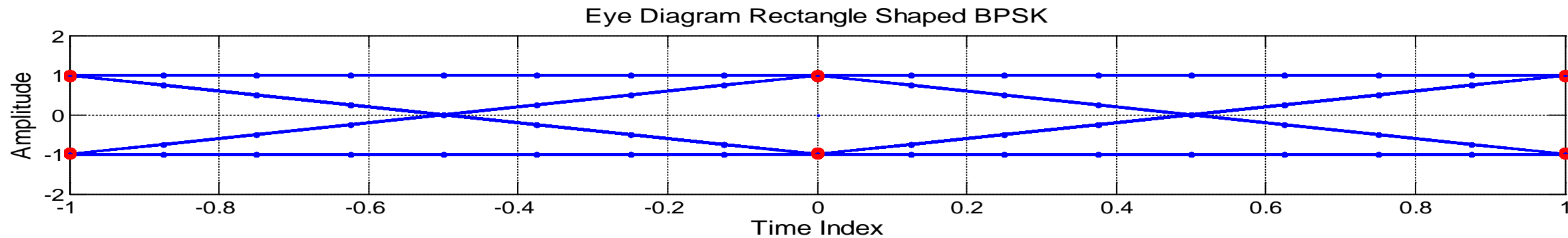




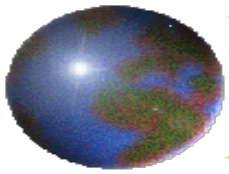
# Acquisition and Tracking Loop for Maximum Likelihood Timing of Rectangle Signal with Self Dither Noise



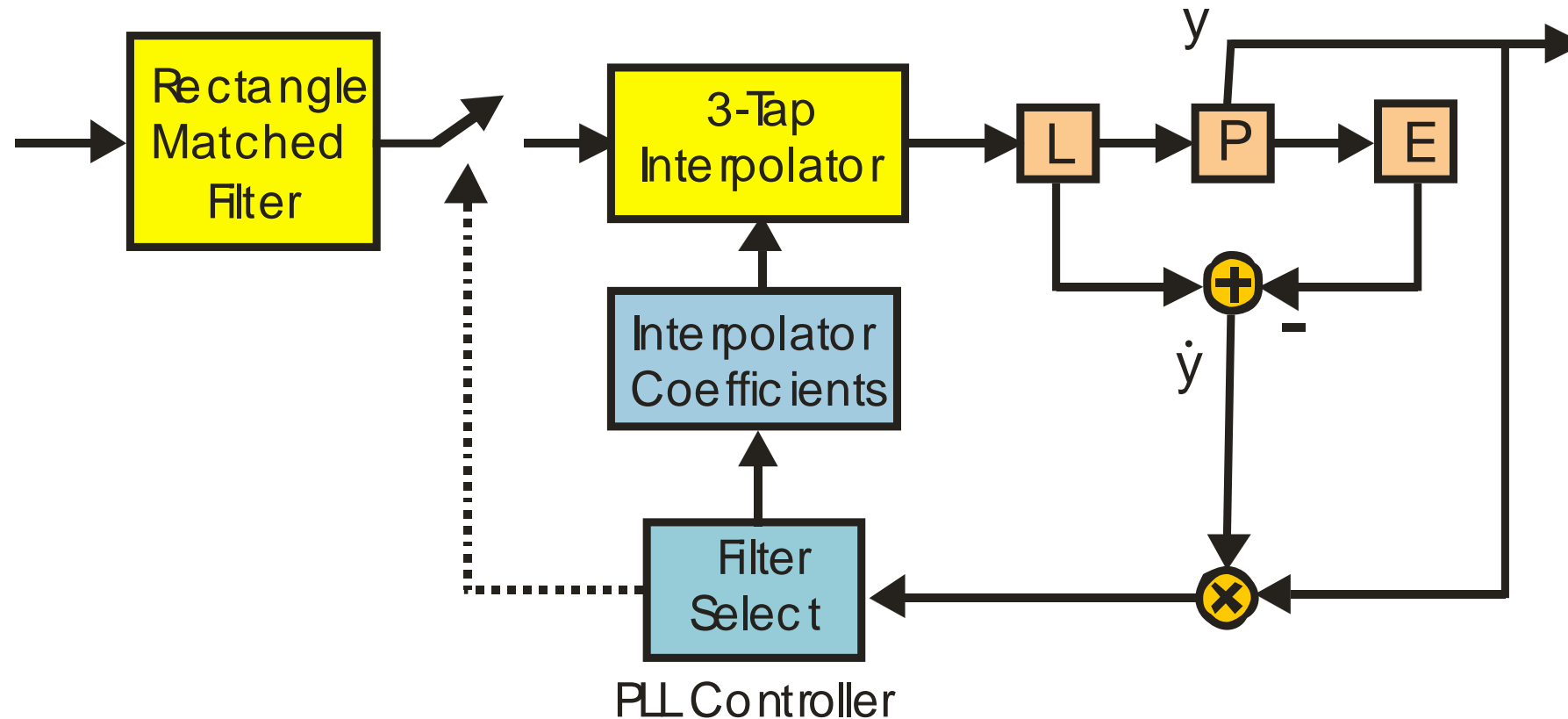
Dither Noise Near Correlation Peaks

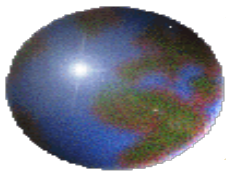




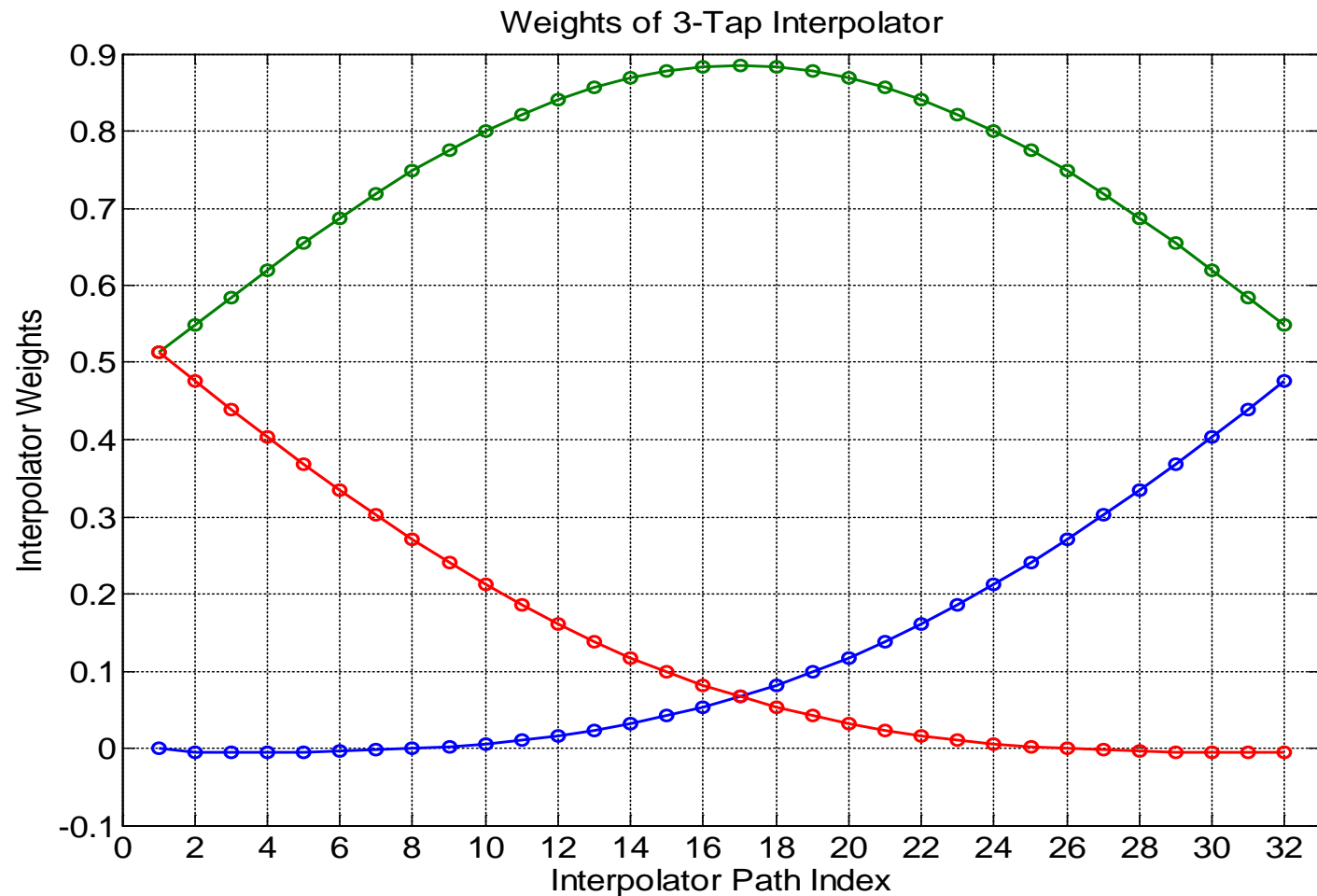


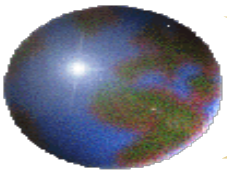
## Timing Recovery Aided by Interpolator to Improve Time Increment Resolution and Suppress Dither Near Correlation Peak



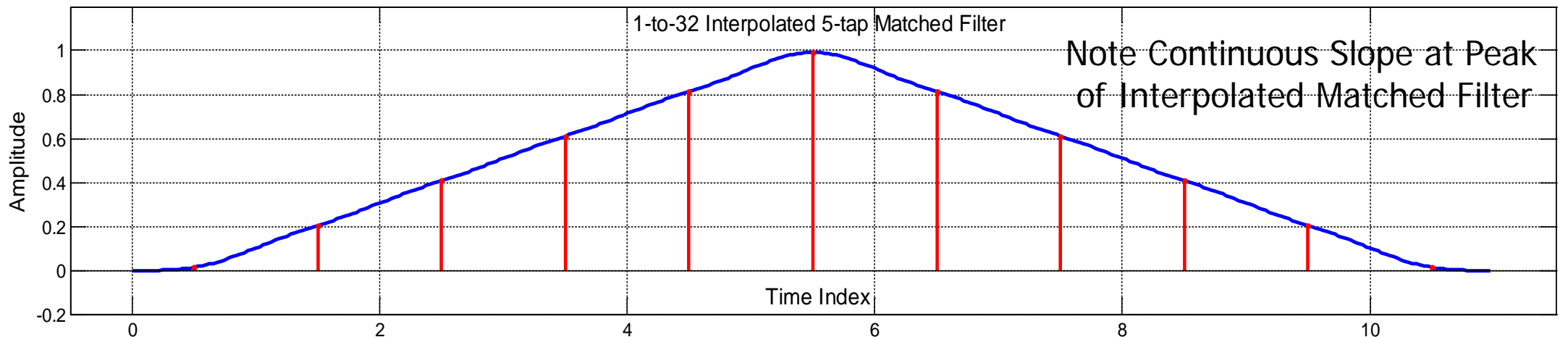
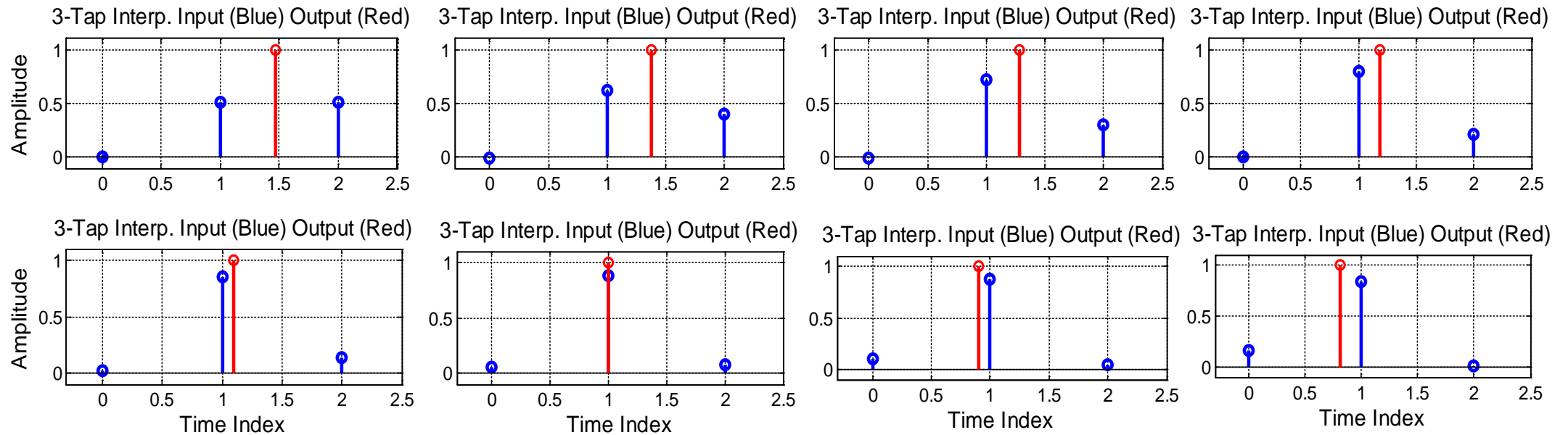


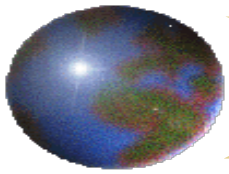
## Interpolator Weights, 32-Sets of 3-taps Per Path.



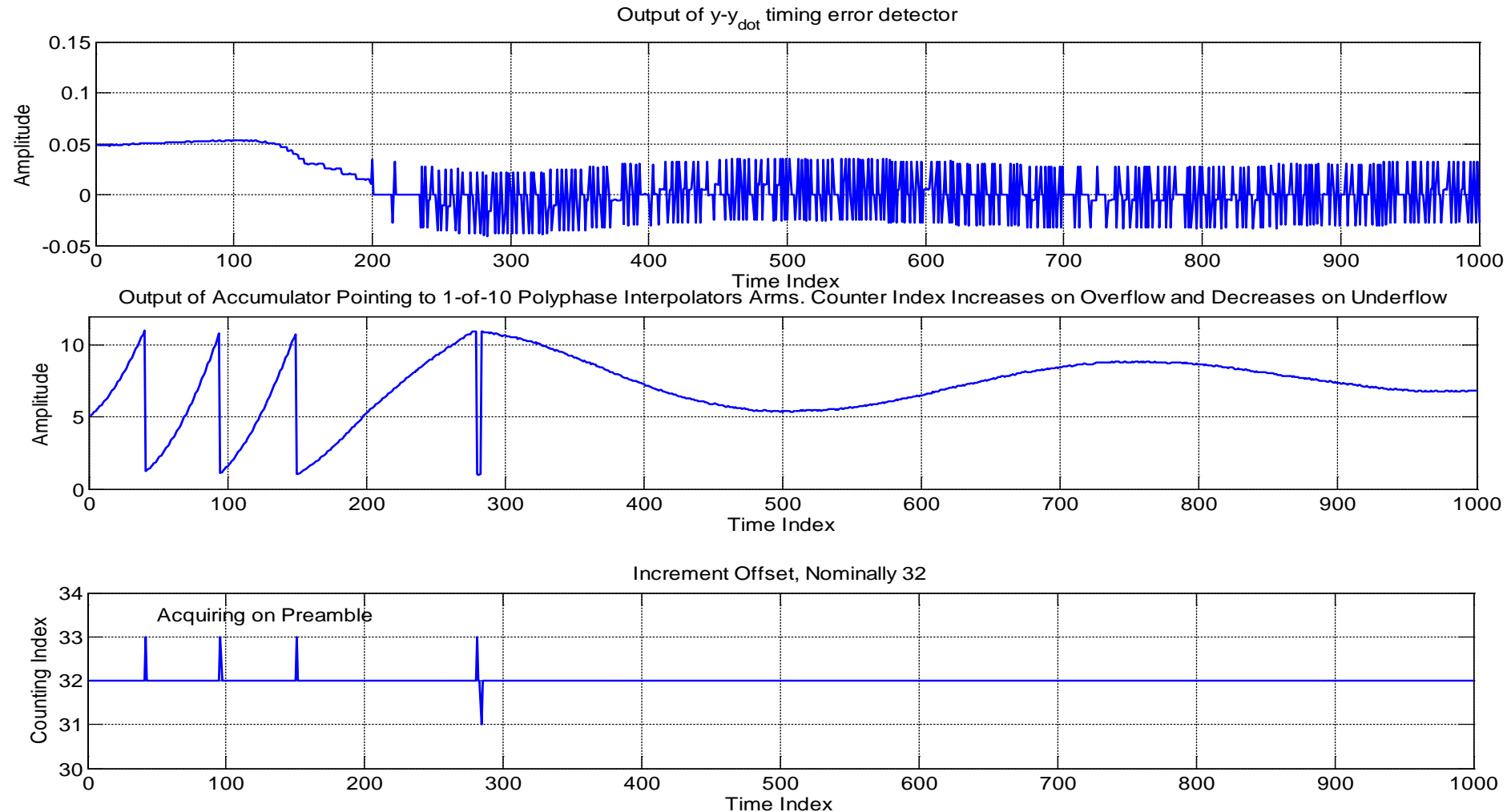


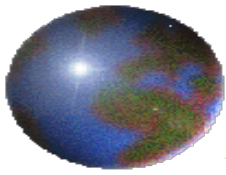
# Interpolator Response for Three Tap Interpolator: Different Offsets and Interpolated Correlator of 5-tap Rectangle Matched Filter



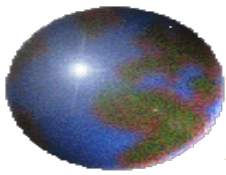


# Acquisition and Tracking Loop for Maximum Likelihood Timing of Rectangle Signal with Interpolated Matched Filter Suppressing Self Dither Noise

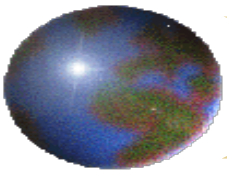




Professor harris, may I be excused?  
My brain is full.



“It’s up to you, either synch or swim.”



Questions?