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Effect of Decorrelation on Butterfly Search Velocity Estimator Performance

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ABSTRACT

The effect of signal decorrelation on the performance of the Butterfly Search velocity estimator is examined. An analytical approximation for the expected value of the Butterfly Search $L(v)$ function is developed for three cases of interest. The approximations are verified against synthesized echo data. It is found that the peak value of the [illegible]

where $h(t)$ is the two-way transfer function of the transducer, G is a scale factor, d_0 the depth at $n = 0$, c the speed [redacted]

Doppler frequency shift of the signal.

[redacted] on n is determined by the target velocity v. Any non-zero velocity results in a time [redacted]

Note that the left hand side is less than or equal to a constant. Since equality is achieved only when $g_1 = kg_2$, the left hand side will reach its peak only in the presence of a DC signal. Simplifying the above equation yields

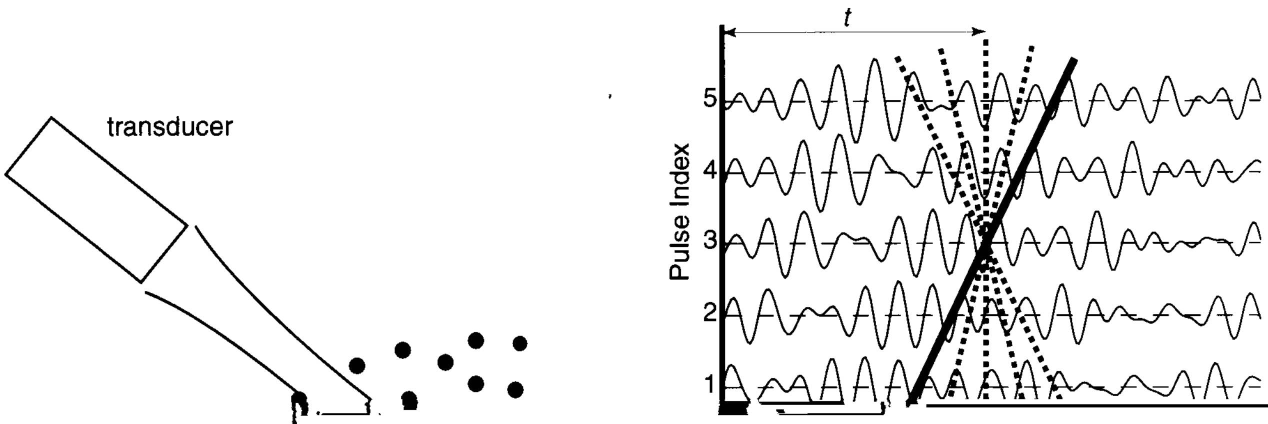
[illegible]

Inserting the re-sampled signal $r_n(t, \nu)$ for g_1 finally gives the expression for $L(t, \nu)$

$$L(t,\nu) = \frac{\left|\sum_{n=0}^{N-1} r_n(t,\nu)\right|^2}{\sum_{n=0}^{N-1} |r_n(t,\nu)|^2} \qquad (6)$$

This is the $L(v)$ function on RF of Alam and Parker, expanded as a function of time (depth). L takes on a maximum

[illegible]



[redacted]

Uncorrelated Noise The next degree of complexity involves a constant signal in the presence of noise. In this case, the random vector **Z** is described by

where a is a real constant, and $\varsigma_i = x_i + jy_i$, where x and y are independent Gaussian random variables, with zero mean and variance σ^2, representing additive noise. The expression for the expected value of L my be written

$$E\{L\} = 1 \cdot \sum^{n-1} \sum^{n} \left(E\left\{ \frac{2a^2}{\cdots} \right\} + E\left\{ \frac{a\varsigma_i + a\varsigma_i^*}{\cdots} \right\} + E\left\{ \frac{a\varsigma_j + a\varsigma_j^*}{\cdots} \right\} + \left\{ \frac{\varsigma_i^*\varsigma_j + \varsigma_i\varsigma_j^*}{\cdots} \right\} \right) \qquad (13)$$

The expression for the expected value is then

$$\left(\frac{z_i^* z_i + z_i z_i^*}{\ldots} \;\; \frac{z_i^* \varsigma_i + z_i \varsigma_i^*}{\ldots} \;\; \frac{z_i^* \varsigma_i + z_i \varsigma_i^*}{\ldots} - \frac{\varsigma_i^* \varsigma_i + \varsigma_i \varsigma_i^*}{\ldots} \right)$$

The last three expected values can be taken to be zero. The leftmost expectation presents a problem in that the numerator and denominator terms are not independent. In order to attempt an analytical approximation, the

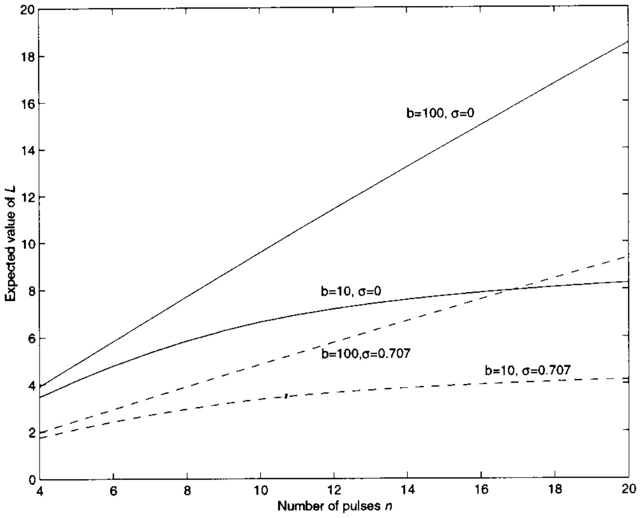


Figure 4. Expected value of L as a function of n. $a = 1$ for all traces.

[redacted]

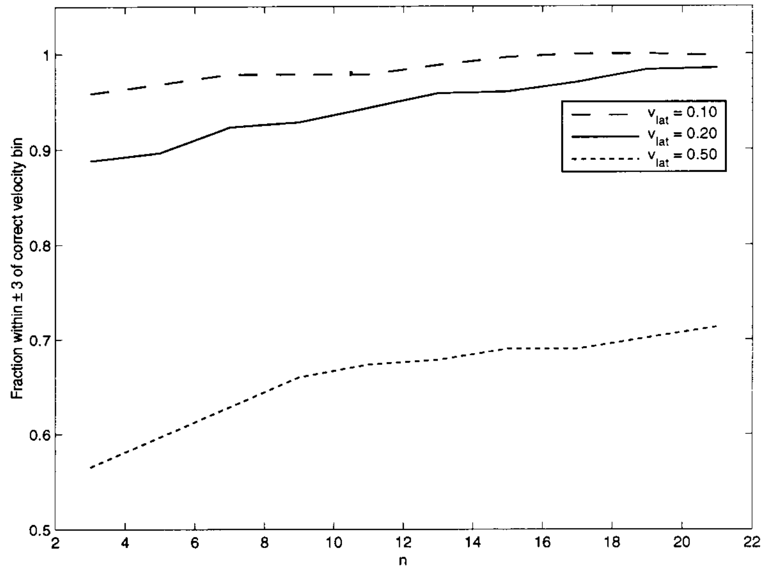
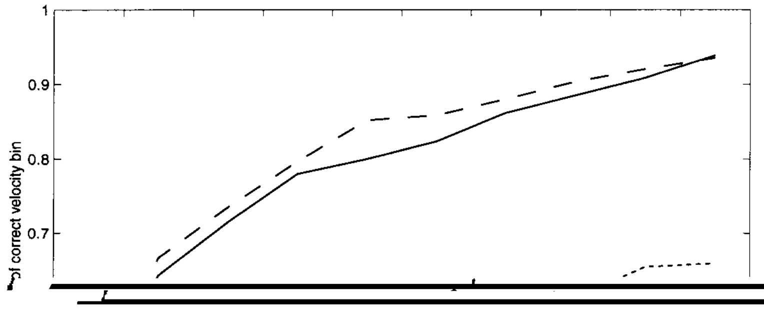


Figure 5. Fraction of velocity estimates within ±3 velocity bins for lateral velocities of 0.1, 0.2 and 0.5 m/s, SNR $= \infty$



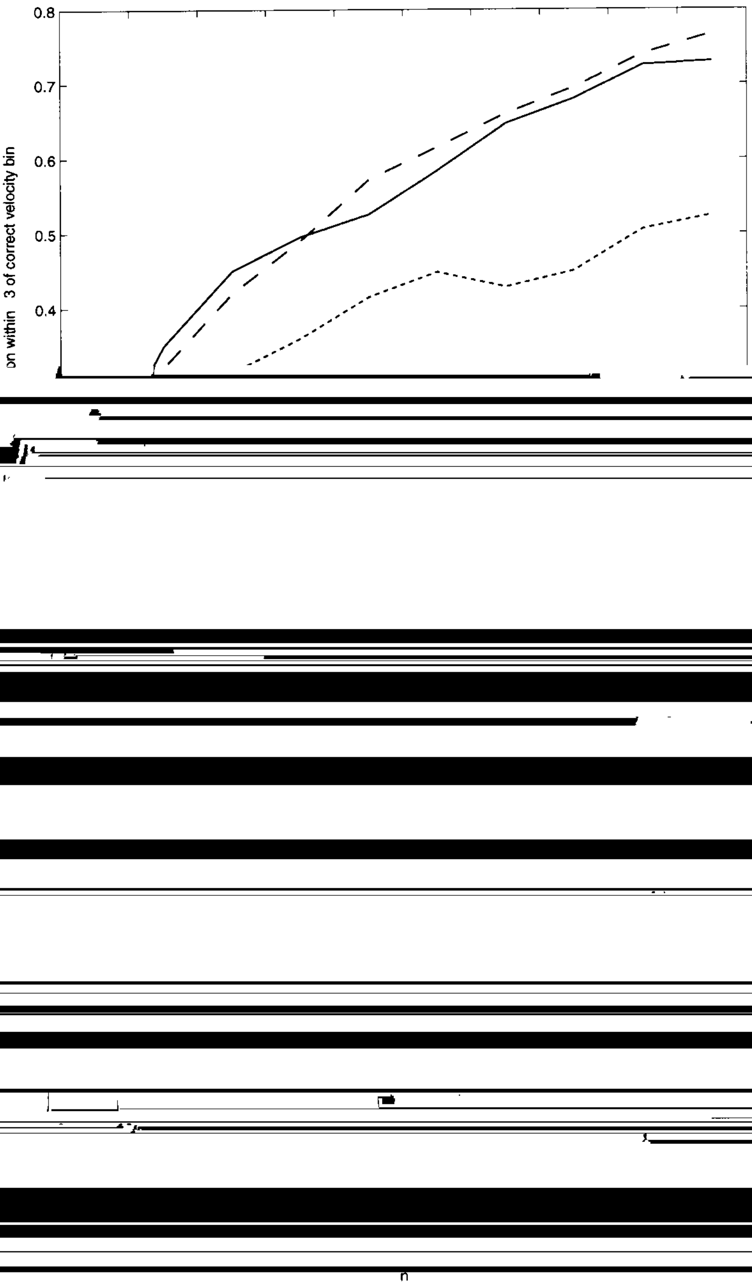
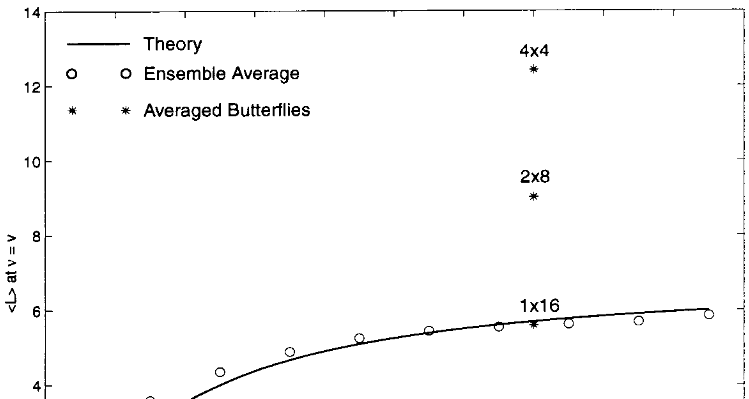


Figure 7. Fraction of velocity estimates within ±3 velocity bins for lateral velocities of 0.1, 0.2 and 0.5 m/s, SNR = 0dB.



[redacted]

A-lines.

SNR = ∞

	v_{lateral}(m/s)						
	0.00	0.01	0.02	0.05	0.10	0.20	0.50
1:16	1.00	1.00	1.00	1.00	1.00	0.96	0.69
2:8	1.00	1.00	1.00	1.00	1.00	0.97	0.72
4:4	1.00	1.00	1.00	1.00	1.00	1.00	0.86

SNR = 6dB

	v_{lateral}(m/s)						
	0.00	0.01	0.02	0.05	0.10	0.20	0.50
1:16	0.88	0.89	0.90	0.90	0.89	0.88	0.63
2:8	0.81	0.84	0.84	0.82	0.83	0.87	0.63
4:4	0.72	0.73	0.72	0.73	0.76	0.82	0.71

SNR = 0dB

	v_{lateral}(m/s)						
	0.00	0.01	0.02	0.05	0.10	0.20	0.50
1:16	0.69	0.71	0.70	0.69	0.68	0.67	0.42

[redacted]

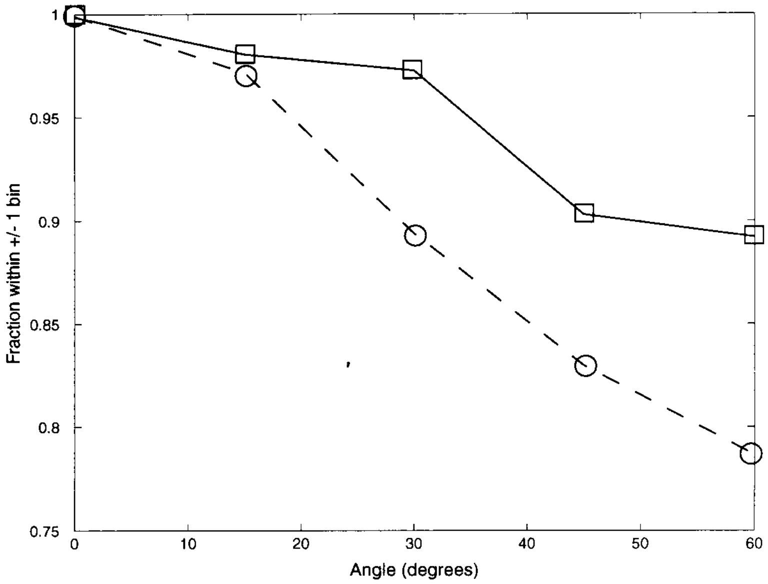


Figure 9. Performance of Butterfly estimator on water tank data versus angle. Circles denote data points for calculation using a one Butterfly of 16 A-lines. Squares indicate results for the average of four Butterflies of four A-lines each..

5. CONCLUSION

The effect of echo-to-echo decorrelation on Butterfly Search estimation has been assessed. An analytical approximation to the expected value of the L function has been found for several cases of interest, and all are found to be in good agreement with results obtained by ensemble averaging. The approximations indicate that the maximum value of the L function is limited by the rate of signal decorrelation. Simulations show that this correlates well with the ... by the Butterfly Search on decorrelated data. Finally, it is found ...

8. S. Alam and K. Parker, "Reduction of computational complexity in the butterfly search technique ultrasonic [illegible]