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VIBRATION AND ACCELERATION-INDUCED TIMING ERRORS OF CLOCKS AND CLOCK SYSTEMS

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Summary

There is an increasing interest in using precision atomic clocks in field applications where the frequency stability is usually dominated by environmental parameters such as vibration, acceleration, temperature variations, magnetic field changes, etc., instead of by the intrinsic noise processes. For highly mobile platforms, the acceleration sensitivity often contributes the largest timing errors for short measurement intervals. Local oscillator frequency modulation may be reduced somewhat by the frequency lock to the atomic resonance. It may also result in a dc offset through non-linear interaction with the atomic resonator modulation.

The vibration/acceleration sensitivity of atomic clocks is shown to be intrinsically very small, but not zero. The observed sensitivity has two major components; the first is due to the quartz crystal controlled local oscillator, and the second is due to the physical displacement of the platform. The first component causes a phase modulation of the clock output at low vibration/acceleration levels, while at high levels the output frequency and time become decoupled from the atomic resonance, thereby losing precision. The second component is present even with a perfect clock and is due to the first order Doppler effect coming from the instantaneous velocity of the platform. A high platform vibration level precludes accurate velocity measurements unless one averages for a long time and/or uses a compensation scheme. A three-dimensional acceleration sensor plus a compensation network can accommodate and correct for both the oscillator and platform sensitivities at low vibration levels. On the other hand, high vibration levels call for a new approach.

Since clock frequency and timing depend on the sum of all environmental and noise processes, some care is needed in specifying worst case timing. The usual case of adding these clock errors in quadrature is examined.