Effects of Delay on Coupled Sensor Systems

The coupled-core fluxgate magnetometer (CCFM) is a magnetic sensor, which is an improvement upon the single fluxgate sensor in signal measurement sensitivity. The proper operation of the CCFM requires oscillatory behavior in the dynamics of the device to drive it in and out of saturation. Though the dynamical equations well approximate the behavior of the actual device, a small time delay in the coupling is assumed due to finite signal transmission times. The simplest case of a CCFM system exhibiting oscillations (three coupled cores) is studied. The corresponding system of equations exhibits rich dynamical behavior in the region of operation of the device. It is determined in this region that a stable limit cycle and two nontrivial synchronous equilibria have large basins of attraction. The size of this basin of attraction varies for different values of coupling strength and time delay. For a small continuous band of values of the coupling strength (\(\lambda\)), sufficiently increasing the time delay (\(\tau\)) induces a Hopf bifurcation in the dynamics. Since the Hopf bifurcation renders the synchronous equilibria unstable, all nonsynchronous solutions are repelled onto the only stable attractor in this regime, the stable limit cycle. The effects of a small time-delay may actually benefit the system by causing it to oscillate more easily.

Figures: (Top left) Second-generation of embedded fluxgates made up of annealed Cobalt-based Metglas 2714A cores. (Top right) Hardware Prototype of a Coupled-Core Fluxgate magnetometer. (Middle left) Locus of delay-induced Hopf bifurcation in (\(\lambda, \tau\)) parameter space. The basin of attraction of the synchronous equilibria for several time delay values: A (Middle right), B (Bottom left), C (Bottom right).

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