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Taming Noisy, Unstable Plasma using Feedback

Achieving the highest possible fusion performance in the future will be critically enabled by the development of new strategies for feedback control of unstable plasmas

DALLAS, Texas – Recent experiments at the Columbia University Plasma Physics Laboratory (New York City) have demonstrated control of noisy, unstable plasmas using an advanced feedback algorithm called a Kalman filter for the first time. The Kalman filter algorithm successfully removed noise from the feedback signals, allowing the plasma instability to be successfully targeted.

In order to maximize the power output of future fusion reactors, plasmas must be made at very high pressure. However, raising the pressure beyond a certain threshold leads to a surface wave instability that causes the plasma boundary to distort and kink. If the pressure remains too high, these surface perturbations grow to large amplitude and lead to rapid loss of the magnetically confined plasma. By sensing these unstable surface waves when they grow it is now possible to use arrays of magnetic coils to push back on the plasma surface when it becomes unstable, raising the current and pressure at which plasma devices can operate. Such feedback systems, however, frequently encounter problems with noise. Because plasmas frequently have noisy activity, the development of feedback algorithms that can differentiate noise from the onset of an instability is crucial for the success of feedback and the confinement of high pressure plasmas. Recent experiments using Kalman filtering *(See Fig. 1.)* have demonstrated the ability to discriminate the unstable surface kink perturbation from additive “white” noise allowing feedback suppression of the kinking plasma.

A Kalman filter is a sophisticated identification algorithm that works by comparing a mathematical model for the kinking plasma with actual magnetic measurements of the deforming plasma in real time. This produces an estimate of the surface kink wave’s true amplitude. Named after one of its principal inventors, Rudolph Kalman, the Kalman filter was first applied to the problem of estimating spacecraft trajectories in the Apollo program. The use of a mathematical model allows the filter to correct for shortcomings in the measurements such as noise or lack of completeness. Likewise, information from the measurements can address limitations in the physical model of the kinking plasma.

In plasma feedback control experiments at Columbia University, Kalman filtering greatly reduced the amplification of noise by the kink feedback system. In further testing, artificial noise was added to feedback signals at levels that prevented the feedback system from suppressing the plasma instability. When the Kalman filter algorithm was turned on, the effect of this extra noise was eliminated and the feedback system was again able to suppress the kinking plasma motion.

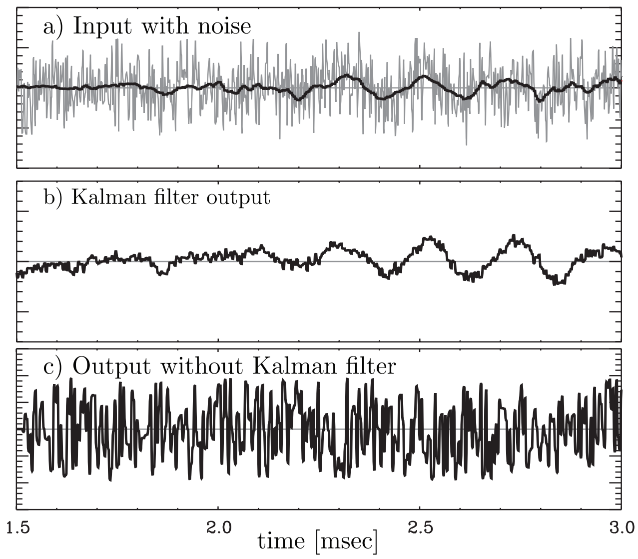

Figure 1: The Kalman filter does an excellent job of eliminating noise from input signals. Part a) shows a typical input signal, with added noise. Part b) shows the Kalman filter's output and part c) shows the output of the filter algorithm without the Kalman filter.

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Feedback Suppression of Rotating External Kink Modes in the Presence of Noise

Invited Session BI2: Rotation in Tokamaks
11:15 AM–11:45 AM Monday, November 17, 2008
Landmark B

Further information: Physics of Plasmas **15**, 080704 (2008)