Characterization of off-axis fishbones

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Abstract.

Repetitive bursting instabilities with strong frequency chirping occur in high beta, beam-heated plasmas with safety factor $q > 1$ in the DIII-D tokamak. Although the mode structures differ, in many ways, the off-axis fishbones are similar to the $q = 1$ fishbones first observed on the Poloidal Divertor Experiment (PDX). The modes are driven by energetic trapped ions at the fast-ion precession frequency. During a burst, the frequency changes most rapidly as the mode reaches its maximum amplitude. Larger amplitude bursts have larger growth rates and frequency chirps. Unlike PDX fishbones, the decay phase is highly variable and is usually shorter than the growth phase. Also, the waveform is highly distorted by higher harmonics during the latter portion of a burst. The radial mode structure alters its shape during the burst. Like PDX fishbones, the modes expel trapped ions in a "beacon" with a definite phase relationship relative to the mode. Seven types of loss detectors measure the beacon. The losses scale linearly with mode amplitude. The neutron rate changes most rapidly at maximum mode amplitude but, depending on the loss diagnostic, the losses often peak a few cycles later. The non-ambipolar fast-ion losses cause a sudden change in toroidal rotation frequency across the entire plasma. In addition to an overall drop, the neutron signal oscillates in response to the wave. Unlike the beacon of lost particles, which maintains a fixed phase relative to the mode, the phase of the neutron oscillations steadily increases throughout the burst, with the greatest phase slippage occurring in the highly nonlinear phase near maximum mode amplitude.