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The origin of Saturn's variable radio modulation period

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Measurements of the electron density in the inner region of Saturn's plasma disk, from about 3 to 5 Saturn radii (R_S), have shown that the plasma density has a large rotational modulation that is synchronous with the time variable rotational period of the Saturn kilometric radiation (SKR). The plasma density and SKR modulations are also shown to be locked to the rotating magnetic field structure in the plasma disk. This relationship suggests that the modulation of Saturn's radio emission has its origins deep in the plasma disk, near the orbit of Saturn's moon Enceladus at 3.95 R_S. We propose that the rotational modulation arises from a centrifugal instability in the inner regions of the plasma disk that causes an asymmetrical outflow of plasma, originating from the Enceladus gas torus, that slips slowly in phase relative to Saturn. Langmuir probe measurements show direct evidence of this periodic outflow, with a rotational phase lag that gradually increases with increasing radial distance beyond about 10 R_S. In this model the slippage rate is determined by the electrodynamic coupling of the plasma disk to the upper atmosphere of Saturn via field-aligned currents, and by mass loading from the neutral gas torus formed by the ejection of plumes of water from Enceladus. The density modulation, which is nearly sinusoidal near the orbit of Enceladus, suggests that the instability is dominated by the azimuthal m = 1 mode, which yields a two-cell convection pattern in the inner region of the plasma disk. The outflow of plasma from this rotating convection pattern acts as the "camshaft" that drives other rotationally modulated processes farther out in the magnetosphere, such as the SKR. Variations in the period of the SKR modulation would then be determined by two factors, variations in the coupling of the plasma disk to the upper atmosphere of Saturn (due to seasonal changes in the ionospheric conductivity), and variations in the rate at which mass is ejected from Enceladus.