RADIAL DECAY OF BROADBAND MAGNETIC FLUCTUATIONS IN ASDEX

L. Giannone, E. Holzhauer* and J. Gernhardt

Max Planck Institut für Plamsaphysik,
Garching, F. R. G.

* Institut für Plasmaforschung,
Universität Stuttgart, F.R.G

1. INTRODUCTION

A new magnetic probe system, consisting of coils mounted on a pneumatically driven manipulator, has been installed on ASDEX. The manipulator may be scanned through a distance of 8 cm in the radial direction within 150 ms. This system then possesses the capability of obtaining measurements of the radial decay of broadband magnetic fluctuations at a single poloidal location /1/. Other experiments have used coils positioned at different poloidal locations and measured the radial decay by plotting the fluctuation amplitude as a function of the radial position of each coil /2,3/.Measurements of magnetic fluctuation amplitude during L and H transitions were previously made by coils located at a distance of 14 cm from the separatrix /4/. The new coils may be moved to within 4 cm of the separatrix.

2. EXPERIMENT

The radial, poloidal and toroidal components of the fluctuating magnetic field may be detected simultaneously. A passive high pass filter is used to attenuate the dominant coherent magnetic fluctuations due to Mirnov oscillations. The signal is amplified with a gain of 200 and monitored by an analogue-to-digital converter, a spectrum analyser or a frequency comb. The frequency comb contains a splitter and a set of 8 bandpass filters. This allows the RMS amplitude of the probe signal at 8 frequencies in the range 30 kHz to 1 MHz to be measured simultaneously.

The signal-to-noise ratio at distance of 4 cm from the separatrix is greater than 20 dB up to a frequency of 1 MHz for the radial and poloidal components in Ohmic discharges. At low frequencies the toroidal component is smaller than the poloidal and radial components, while at higher frequencies they are of comparable magnitude. In ASDEX, the measured poloidal field contains a component generated by switching noise on the multipole and vertical field coils. Radial profiles of the fluctuation amplitude of the radial component were therefore studied.

The radial decay of broadband magnetic fluctuations was measured by scanning the coils through a distance of 8 cm. The probe starts 12 cm away from the separatrix, moves to within 4 cm of the separatrix and returns (see Fig. 1). The closest distance to the separatrix was determined by observed increases in the hard x-ray flux, which resulted from runaway electron collisions with the probe. Ohmically heated and neutral beam heated plasmas with various values of magnetic field and plasma current have been studied.

The poloidal mode number, m, has been inferred from the radial decay of the magnetic fluctuation amplitude, since in a current free region the amplitude decreases as $r^{-(m+1)}$ in cylindrical geometry /2,3/. This implicitly assumes that the conducting wall is positioned at an infinite distance from the plasma and that the toroidal wavelength is infinite ($k_z = 0$). A plot of the logarithm of the amplitude versus the logarithm of the minor radial positon was used to find m. The decay of magnetic fluctuation amplitude in the presence of a conducting wall at a finite distance from the plasma with $k_z \neq 0$ has been considered /5/. The expected radial decay for a single mode may be expressed in terms of modified Bessel functions. With the conducting wall on ASDEX at r = 61 cm and the separatrix at r = 40 cm, it was found that the m number was overestimated, when the effect of the conducting wall and finite k_z were ignored.

Modes with the lowest m predominate when a number of modes with different m are unstable, because of the strong dependence of the radial decay on m. From these measurements of the radial decay of broadband magnetic fluctuations, it is found that $m \leq 8$ on ASDEX. This value is consistent with those observed in other experiments /1-3/.

3. THEORY

The identification of the plasma instability responsible for the generation of broadband magnetic fluctuations and the extent to which magnetic fluctuations cause anomalous electon transport are important topics in fusion research. It has been suggested that broadband magnetic fluctuations are due to microtearing modes /2,6/. These modes are high m temperature gradient driven tearing modes.

Calculations concerning the linear instability of microtearing modes in ASDEX, show that modes with $m \leq 10$ may be unstable for typical discharge conditions /7/. In Ohmic discharges the unstable modes are located at radial positions inside of half the plasma minor radius, while in neutral beam heated plasmas the most unstable modes are located closer to the plasma boundary (see Fig. 3). This result suggests that the enhanced magnetic fluctuation level measured in neutral beam heated plasmas /4/ may be partly due to a change in the position of the unstable modes, and this should be taken into account in those experiments considering the scaling of the inverse of confinement time, τ_E^{-1}, with broadband magnetic fluctuation amplitude /8/.

4. CONCLUSION

For ASDEX plasma parameters, experimental observations and theoretical calculations suggest that the microtearing mode remains as a candidate for the plasma instability which is responsible for the generation of the broadband magnetic fluctuations.

Further work is required to apply a more sophisticated theory which describes the non-linear and toroidal coupling of different modes and the saturation of each mode to the experiment. In the linear theory each mode generates fluctuations at a frequency determined by the plasma parameters. A broadband spectrum is produced as a result of the non-linear and toroidal coupling of modes that are located at different radial positions within the plasma.

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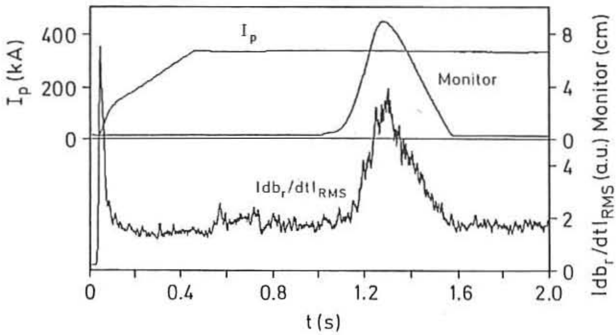

Fig. 1

Fig. 1 The movement of the manipulator is monitored and the radial profile of the RMS amplitude of $\delta b_r/dt$ is measured at $f = 82$ kHz in an Ohmic discharge with $B = 1.85$ T and $I_p = 320$ kA. The bandpass filter has $\Delta f/f = 0.1$.

Fig. 2 Radial decay of broadband magnetic fluctuation amplitude as a function of frequency for an Ohmic discharge. A plot of the logarithm of the amplitude versus the logarithm of the minor radial position yields the poloidal mode number, m. The presence of the conducting wall needs to be taken into account.

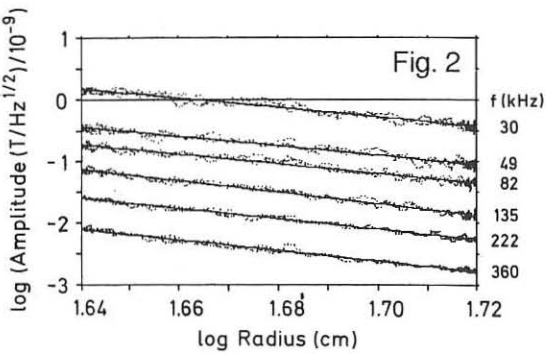

Fig. 3
Microtearing mode stability in a plasma with $B = 1.85$ T and $I_p = 320$ kA. The imaginary part of the eigenvalue, γ, versus normalised radius for an Ohmic discharge is plotted in Fig. 3(a) and for a discharge with neutral beam injection in Fig. 3(b). The mode is unstable when $\gamma > 0$.

Fig. 3