*32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-4.028 (2005)*

High frequency magnetic field fluctuations measured on the RFX-mod experiment with internal coils

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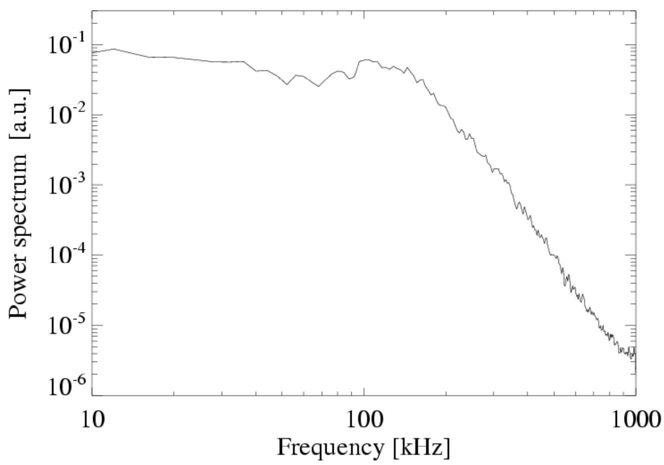
The modified RFX reversed field pinch experiment (RFX-mod) has been equipped with a large set of electrostatic probes and magnetic coils inserted inside the vacuum vessel [1]. One of the main purposes of this system, named ISIS (Internal System of Integrated Sensors) is the study of plasma turbulence in the outer region of the plasma. In this paper we report the first results concerning magnetic fluctuations, which were obtained using a subset of the full ISIS diagnostic. The probes that were used are organized in two partial toroidal arrays of 11 equally spaced probes each, covering 75° of the toroidal circumference, and positioned at 70° and 250° poloidally (the zero being on the outer equator). The probes consist of pick-up coils measuring the time derivative of the toroidal component of the magnetic field. They are located behind the graphite tiles which cover the first wall of the machine. The signals are sampled at 2 MHz, the estimated bandwidth of the measurement is up to 200-400 kHz.

A typical power spectrum of the signal during the flat-top phase of the discharge is shown in Fig. 1. The spectrum is computed dividing the signal into N slices, considered as independent realizations of the random process, and averaging over them [2]. The spectrum shows three main regions: a rather flat low frequency region, a broad peak around 100 kHz, and a high frequency portion which decays as f^{-5}. It is worth mentioning that the peak can be more or less pronounced or also be absent, according to the experimental conditions. The spectrum decay does not show any flattening up to 1 MHz, suggesting that



the effective measurement bandwidth might be substantially larger than the theoretical estimate.

The two partial arrays of probes have been used to determine the spatiotemporal properties of the fluctuations. While two toroidally aligned probes would be enough for a statistical estimation of the wavenumber-frequency spectrum S(k,f), the use of all the probes allowed us to obtain a better determination (k in this case is the toroidal wavenumber, related to the toroidal mode number n by n = kR). The procedure which was adopted is the following: the two partial arrays are considered as parts of two full arrays of 48 equally spaced probes. All the signals of the missing probes, in absence of further information, are put equal to zero. Sums and differences of couples of probes located at the same toroidal locations are computed in order to distinguish between even and odd m contributions (m is the poloidal mode number). Subsequently, a spatial FFT is computed at each time, so as to obtain complex amplitudes as a function of n and t of the modes with even and odd m. The power spectra of the amplitudes are then computed, according to the procedure outlined above, and used to generate the S(n,f) spectrum. A comparison with an estimate of the same quantity computed with the 2-point technique [3] shows that the two procedures yield similar results, but the one adopted here has a better statistical precision, due to the larger number of signals used.

An example of S(n,f) for even m is shown in Fig. 2. A clear linear relationship between n and frequency is observed. The appearance of part of the spectrum on the left hand side of the plot is an aliasing effect due to the distance between two adjacent probes. The slope of the line corresponds to a phase velocity of about 20 km/s. This is of the order of the toroidal plasma flow velocity expected at the edge of the RFX, according to past measurements of the radial electric field, suggesting that the slope of the spectrum might be primarily due to Doppler effect. The propagation direction is in the direction of decreasing toroidal angle.

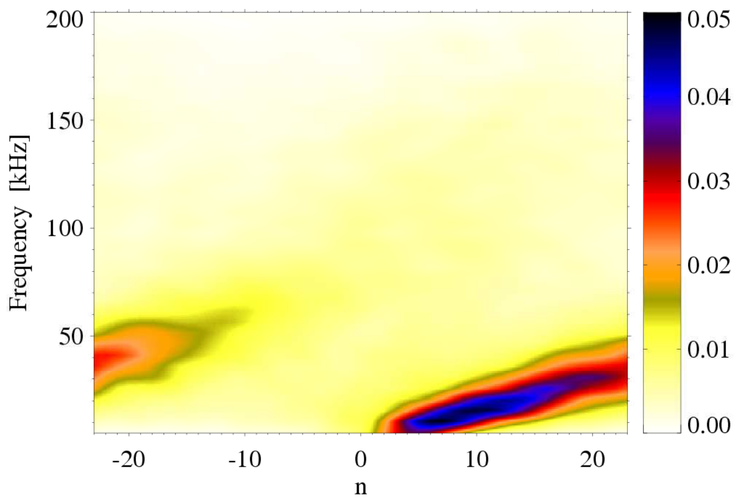


Fig. 2: S(n,f) for even m modes.

The S(n,f) spectrum for odd m modes is depicted in Fig. 3. The graph shows a pronounced peak at a frequency of around 100 kHz. This peak corresponds to the peak observed in Fig. 1. The mode number of the peak appears to be small, and its sign can change from shot to shot. However, the analysis of the same spectrum, using the 2-point technique applied to two probes having a smaller distance (not part of the arrays analysed here) has shown that the actual wavenumber of the peak is positive and high, of the order of n = 40-50. The mode number appears to be small in Fig. 3 due to aliasing. As a consequence, the phase velocity of the peak is of the same order of that of the even m modes shown in Fig. 2, supporting the hypothesis that it is mostly due to a Doppler shift related to plasma propagation.

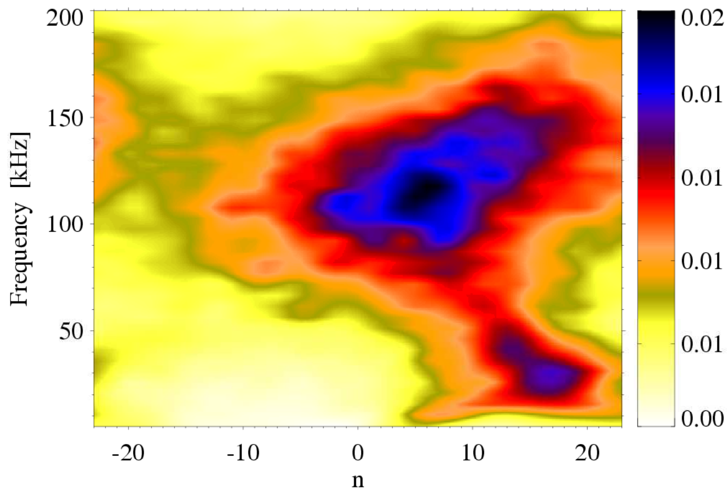


Fig. 3: S(n,f) for odd m modes.

It is interesting to observe that in some occasions (like the one shown in Fig. 3) a lower frequency peak appears, at a frequency of 20-30 kHz. This secondary peak corresponds to mode numbers n = 15-20.

It is known that the edge region of the reversed field pinch is generally governed by a localised distortion of the plasma column, sometimes called slinky mode, which is due to the phase and wall locking of many m=1 tearing modes. While the results presented above are relative to shots, characterised by a mode locking position toroidally distant at least 100° from the closest probe of the diagnostic array, it is interesting to study how the spectra shown above are changed by the presence of

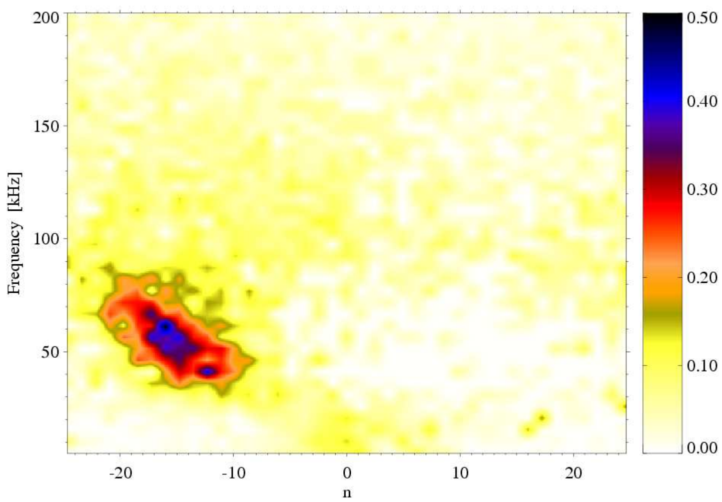


Fig.4: S(n,f) for even m modes near the locking position.

the locked modes. In Fig. 4 the S(n,f) obtained by the 2-point technique applied to two probes in the region close to the locking position is shown for the even m component. The spectrum appears similar to the one shown in fig. 2. However, the propagation direction is reversed, and the velocity is larger (around 50 km/s). According to the hypothesis that the observed velocity is mainly due to the plasma flow, the explanation for its reversal is that the magnetic field perturbation due to the locked modes is associated to a flow velocity perturbation, with an amplitude exceeding the average axisymmetric value.

The frequency of the odd m peak has been found to be related to the plasma density n_e in the machine. A spectrogram (time-frequency plot) of the odd m component (obtained as difference of two probes at the same toroidal location) is shown in Fig. 5. Superimposed to the plot, as a black line, is a frequency proportional to $1/n_e$. A correlation between the spectral peak and the $1/n_e$ signal is found. This correlation points to a possible Alfvenic nature of the observed fluctuations. Indeed, the existence of toroidal Alfven eignemodes (TAEs) in the RFP has been recently suggested [4]. In the present case the observed frequency is relatively low, but this could be explained by the presence of a high content of carbon in the plasma, which is not unlikely due to the fact that the graphite first wall was entirely replaced in RFX-mod, and the new one is probably not yet fully conditioned.

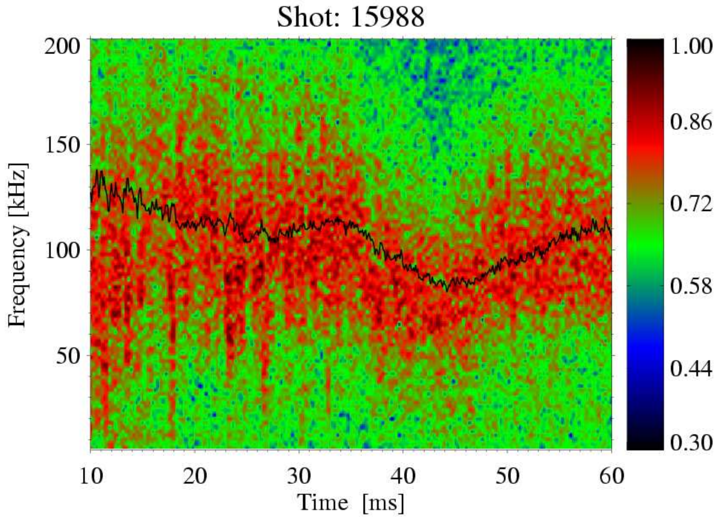


Fig.5: Spectrogram of the odd m component during a phase with non-constant plasma density. The black line is proportional to the inverse of the density.

Acknowledgement *This work, supported by the European Communities under the contract of Association between EURATOM/ENEA, was carried out within the framework the European Fusion Development Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission*

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