Synthetic Mirnov diagnostic for the validation of experimental observations

Paper Rehearsal

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It is observed, that for a high triangularity of the flux surfaces the arrangement of the coils plays a significant role for the exact determination of the poloidal mode number. For the mode analysis torus and PEST coordinates have been used, where in most cases the reconstruction of the poloidal mode number of a prescribed mode is more accurate in PEST coordinates.
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As an application, the signal of an Alfvén eigenmode, which has been calculated with a three dimensional magnetohydrodynamics code, is compared to experimental observations at Wendelstein 7-X.
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As an application, the signal of an Alfvén eigenmode, which has been calculated with a three dimensional magnetohydrodynamics code, is compared to experimental observations at Wendelstein 7-X.

For the chosen example the calculated and measured mode spectra agree very well and additional information on the toroidal mode number and localization of the mode has been inferred.
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Focusing on the capabilities of the hardware and software of the Mirnov diagnostic, an end-end simulation has been developed by D. Testa et al. [8] …

Contribution

1. Systematic analysis about the effect of geometrical properties of the Mirnov coil array and the flux surfaces on the ability to determine the poloidal mode number with the Mirnov diagnostic.
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2. Calculation of the signal of an Alfvén eigenmode in the Mirnov coils for a direct comparison to experimental measurements at Wendelstein 7-X.
Contribution

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2. Calculation of the signal of an Alfvén eigenmode in the Mirnov coils for a direct comparison to experimental measurements at Wendelstein 7-X.

3. Using two different coordinate systems to investigate the effect on the reconstruction of the poloidal mode number of a prescribed mode.
Implementation

- Mode
  - Magn. field at selected flux surface
  - Equilibrium magn. field
Implementation

Mode

Magn. field at selected flux surface

EXTENDER [10]

Magn. field at coil positions

Equilibrium magn. field

Mirnov coil positions

Implementation

- Mode
- Orientation of Mirnov coils
- Magn. field at selected flux surface
  - EXTENDER [10]
  - Magn. field at coil positions
  - Mirnov signal

- Equilibrium magn. field
- Mirnov coil positions
Implementation

- **Mode**
  - Magn. field at selected flux surface
  - Equilibrium magn. field
  - Mirnov coil positions

- **Orientation of Mirnov coils**
  - Magn. field at coil positions
  - Mirnov signal
  - FFT

- **Poloidal angle of Mirnov coils**

Implementation

Calculation of the **Mirnov signal at the coil positions** of a prescribed mode taking into account the spatial distance between the mode and the Mirnov coils.

Effects of geometrical properties: 8 test cases

Eight test cases with varying magnetic field configurations and different arrangements of 41 Mirnov coils.
Effects of geometrical properties: 8 test cases

Eight test cases with varying magnetic field configurations and different arrangements of 41 Mirnov coils.

(a): case 1  (b): case 2  (c): case 3  (d): case 4
(e): case 5  (f): case 6  (g): case 7  (h): case 8

(ln)correct determination of the poloidal mode number

$m_{1\text{st peak}} = m_{\text{input}}$  $m_{1\text{st peak}} \neq m_{\text{input}}$
Effects of geometrical properties on the mode spectrum

PEST coordinates have a higher resolution than torus coordinates.
Effects of geometrical properties

In most cases the reconstruction of the poloidal mode number is more accurate in PEST coordinates.

For a triangular plasma shape, the resolution highly depends on the coil arrangement.
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Experimental mode in a high performance plasma at W7-X during OP1.2
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Mode with $f = 183\text{kHz}$, $m = \pm 2, \pm 4$ showing Alfvénic characteristics.
Alfvén eigenmode calculated with the CKA code

Experimental mode: $f = 183\text{kHz}$, $m = \pm 2, \pm 4$

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Alfvén eigenmode calculated with the CKA code

Experimental mode: $f = 183\text{kHz}$, $m = \pm 2, \pm 4$

Calculated mode: $f = 219\text{kHz}$, $m = -4, -2, n = 3, 3$


Comparison of calculated mode to experimental results

(a) 20180918.041, t=3.4s

- $f=183\,\text{kHz}$

(b)

- $f=219\,\text{kHz}$

(c)

(d)
Comparison of calculated mode to experimental results

The experimental mode can be described as an EAE with $|m| = 2, 4$ and $|n| = 3, 3$ located in the outer region of the plasma.
Conclusions

- The **capability** of a Mirnov diagnostic **depends on geometrical properties** and can vary for different magnetic field configurations (e.g. different experimental programs).
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- PEST coordinates have a higher poloidal mode number resolution than torus coordinates in the eight test cases investigated.
Conclusions

• The capability of a Mirnov diagnostic depends on geometrical properties and can vary for different magnetic field configurations (e.g. different experimental programs).

• For a triangular plasma shape, the resolution highly depends on the coil arrangement.

• PEST coordinates have a higher poloidal mode number resolution than torus coordinates in the eight test cases investigated.

• With the synthetic Mirnov diagnostic, it is possible to directly compare experimental and calculated mode spectra and receive further information about the experimental mode, as e.g. the toroidal mode number and its localization.

References

References

Further distinction of the quality of a mode spectrum

**IMP (input mode’s peak):**
Amplitude of the poloidal mode number of the **prescribed mode**

**FAP (first additional peak):**
Amplitude of the highest peak in the mode spectrum that is **not the IMP**

→ With **increasing** poloidal mode number $m$ the **IMP** gets **less pronounced**
Mirnov signal and resolution depending on the localization of the mode

For core localized modes a correct determination of the poloidal mode number is not possible due to a strong decay of the signals amplitude, even for low poloidal mode numbers.
Resolution of higher poloidal mode numbers

Higher poloidal mode numbers can only be reconstructed correctly, if the geometry of the coil array is similar to the shape of the flux surfaces