Comments on the article 'Numerical study on neoclassical tearing mode stabilization via minimum seeking method for the island width growth rate'

C J Rapson[1], D A Humphreys[2], M Maraschek[1], W Treutterer[1]
1 Max Planck Institute for Plasma Physics, Boltzmannstrasse 2, 85748 Garching, Germany
2 General Atomics, P.O. Box 85608, San Diego, CA 92186-5608, USA
E-mail: chris.rapson@ipp.mpg.de

PACS numbers: 52.55.Tn, 52.50.Sw, 52.65.-y
Keywords Neoclassical Tearing Mode, NTM, simulation, feedback control Submitted to:

Nucl. Fusion

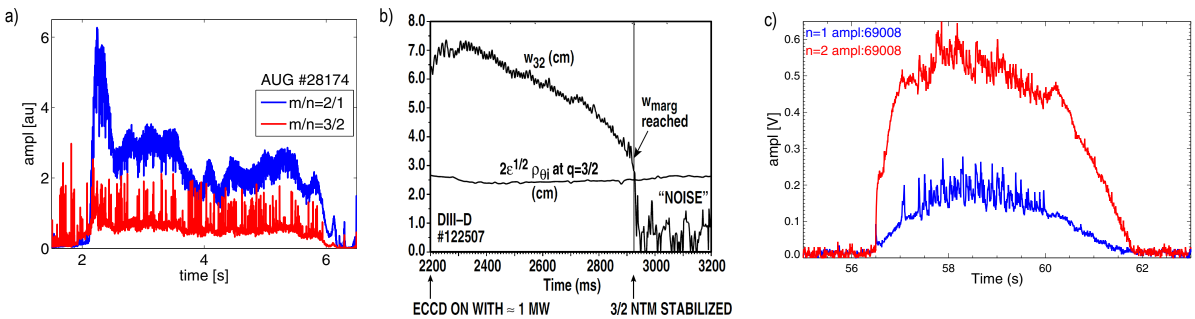

Figure 1. Examples of measurements of the amplitude of magnetic field fluctuations $\left|\dot{B}\right|$, which is usually used to estimate the NTM island width. Measurements are shown from various experiments:
a) ASDEX Upgrade
b) DIII-D, reproduced with permission from fig.3 in [2]. Original caption: Stabilization of an m/n = 3/2 NTM in DIII-D by ECCD. The island width w32 (from Mirnov analysis calibrated by ECE radiometer) decreases steadily until the marginal condition at just above twice the ion banana width ($2\epsilon^{1/2}\rho_{\theta i}$) is reached. Both radial widths are in centimetres.
c) JET.

The discussion in paper [1] is centred around the optimal method to localise a neoclassical tearing mode (NTM). Specifically, the authors compare two methods using the response of the NTM to a nearby Electron Cyclotron (EC) beam, since the closer the centre of the EC beam is to the centre of the NTM, the stronger the stabilising effect will be. The paper in question compares the efficacy of using the amplitude of the NTM (island width, $w(t)$) or the island width growth rate $\frac{dw(t)}{dt}$ for a controller. The paper concludes that using the island width growth rate is both faster and more robust.

However, the comparison is made using a numerical simulation which in this case is entirely free of noise. A comment is made in the last sentence of [1], indicating that future studies will consider the effect of noisy measurements on the results presented here. It is our view that publishing results without considering noise is at best premature, and at worst misleading, since a wealth of experimental evidence such as the measurements shown in fig. 1 and reported in e.g. [3, 4, 5, 6] demonstrate that the noise is significant, with the consensus estimate being approximately 10% of the signal amplitude for a saturated NTM [7]. The noise is dominated by plasma dynamics, especially ELM, sawteeth and fishbone activity, and has significant amplitude at high frequencies. Taking the time derivative to obtain $\frac{dw(t)}{dt}$ amplifies the high frequency noise component, making it very difficult to use these signals in a real-time controller. Previous studies [8, 9, 10] have already addressed the problem of using these noisy signals for exactly the problem of NTM localisation, and found it to be a major restriction in designing a robust controller.

The noise can be mitigated to some extent by applying a low-pass filter. However, this inevitably results in a phase shift, while avoiding phase shifts was one of the reasons given in [1] for favouring the island width growth rate $\frac{dw(t)}{dt}$ over the island width $w(t)$. Furthermore, the authors in [1] assume "that the control time interval is small enough so that the island width growth rate and the island width space do not vary significantly." Discussions in [8, 10] conclude that the control interval should be on the order of 100 ms in order to minimise adverse effects from the noise. The timescale for NTM evolution is of the order of 100 ms in these experiments, so also this assumption would be invalid in a realistic environment at any of today's experiments. In larger future experiments, such as ITER, the timescales may be different, but also the characteristic of the noise may be different. For any controller design claiming robustness, both factors must be taken into consideration.

1. Acknowledgements

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

In addition, the authors would like to acknowledge and thank the ASDEX Upgrade Team and the JET Contributors, for their work in running the experiments and collecting the data presented in this paper.

References

[1] Kim M, Kim K, Yoo M, Na D, Hahm T, Hwang Y and Na Y S 2015 *Nucl. Fusion* **55** 023006 URL `http://stacks.iop.org/0029-5515/55/i=2/a=023006`

[2] La Haye R, Prater R, Buttery R, Hayashi N, Isayama A, Maraschek M, Urso L and Zohm H 2006 *Nucl. Fusion* **46** 451 URL `http://stacks.iop.org/0029-5515/46/i=4/a=006`

[3] Hender T C, Wesley J C, Bialek J, Bondeson A, Boozer A H, Buttery R J, Garofalo A, Goodman T P, Granetz R S, Gribov Y, Gruber O, Gryaznevich M, Giruzzi G, Guenter S, Hayashi N, Helander P, Hegna C C, Howell D F, Humphreys D A, Huysmans G T A, Hyatt A W, Isayama A, Jardin S C, Kawano Y, Kellman A, Kessel C, Koslowski H R, La Haye R J, Lazzaro E, Liu Y Q, Lukash V, Manickam J, Medvedev S, Mertens V, Mirnov S V, Nakamura Y, Navratil G, Okabayashi M, Ozeki T, Paccagnella R, Pautasso G, Porcelli F, Pustovitov V D, Riccardo V, Sato M, Sauter O, Schaffer M J, Shimada M, Sonato P, Strait E J, Sugihara M, Takechi M, Turnbull A D, Westerhof E, Whyte D G, Yoshino R, Zohm H and ITPA MHD D M C 2007 *Nucl. Fusion* **47** S128–S202 ISSN 0029-5515

[4] Buttery R, La Haye R, Gohil P, Jackson G, Reimerdes H and Strait E 2008 *Phys. Plasmas* **15**(5) 056115–1–8 ISSN 1070-664X

[5] Isayama A, Matsunaga G, Kobayashi T, Moriyama S, Oyama N, Sakamoto Y, Suzuki T, Urano H, Hayashi N, Kamada Y, Ozeki T, Hirano Y, Urso L, Zohm H, Maraschek M, Hobirk J, Nagasaki K and Team J 2009 *Nucl. Fusion* **49** ISSN 0029-5515

[6] Maraschek M 2012 *Nucl. Fusion* **52** 074007 URL `http://stacks.iop.org/0029-5515/52/i=7/a=074007`

[7] Snipes J A, Beltran D, Casper T, Gribov Y, Isayama A, Lister J, Simrock S, Vayakis G, Winter A, Yang Y and Zabeo L 2012 *Fusion Eng. Des.* **87** 1900–1906 ISSN 0920-3796 8th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research, San Francisco, CA, JUN 20-24, 2011

[8] Wehner W and Schuster E 2012 *Nucl. Fusion* **52** 074003 URL `http://stacks.iop.org/0029-5515/52/i=7/a=074003`

[9] Humphreys D, Ferron J, La Haye R, Luce T, Petty C, Prater R and Welander A 2006 *Phys. Plasmas* **13** 056113 (9pp) ISSN 1070-664X 47th Annual Meeting of the Division of Plasma Physics of the American-Physical-Society, Denver, CO, OCT 24-28, 2005

[10] Rapson C, Giannone L, Maraschek M, Reich M, Stober J and Treutterer W 2014 *Fusion Eng. Des.* **89** 568 – 571 ISSN 0920-3796 Proceedings of the 9th IAEA Technical Meeting on Control, Data Acquisition, and Remote Participation for Fusion Research URL `http://www.sciencedirect.com/science/article/pii/S0920379614000088`