EUROPEAN FUSION DEVELOPMENT AGREEMENT

JET

EFDA–JET–CP(03)01-64

L. Zabeo, P. Innocente, A. Murari, K.Guenther, E. Joffrin, D. Mazon, M. Riva
and JET EFDA Contributors

Comparison of Different Approaches to the Real Time Correction of Fringe Jumps at JET

Comparison of Different Approaches to the Real Time Correction of Fringe Jumps at JET

L. Zabeo[1], P. Innocente[2], A. Murari[2], K.Guenther[3], E. Joffrin[1], D. Mazon[1], M. Riva[4] and JET-EFDA contributors *

[1]Association EURATOM-CEA, CEA Cadarache, F-13108, St Paul lez Durance, France
[2]Consorzio RFX Associazione EURATOM-ENEA per la Fusione, 4-35127 Padova, Italy
[3]EURATOM/UKAEA Fusion Association, Culham Science Center, Abingdon, OX14 3DB, UK
[4]Associazione EURATOM-ENEA sulla Fusione, C.R. Frascati, 00044 Frascati, Italy
**See Annex of J. Pamela et al., "Overview of Recent JET Results and Future Perspectives", Fusion Energy 2000 (Proc. 18th Int. Conf. Sorrento, 2000), IAEA, Vienna (2001).*

Preprint of Paper to be submitted for publication in Proceedings of the
EPS Conference on Controlled Fusion and Plasma Physics,
(St. Petersburg, Russia, 7-11 July 2003)

ABSTRACT.
The real time control of various plasma scenarios is one of the most qualifying JET programs on the route to a next step Tokamak. The feasibility of these control schemes depends crucially on the quality and reliability of diagnostics and the plasma density is one of the most frequently required. In this perspective, in JET a fast acquisition system [1] for the interferometer/polarimeter diagnostic [2] has recently been installed. It produces a measurement every millisecond and it has been fully validated in the last campaigns. The main problem faced by the system consists in the fringe jumps, consequence of the strong variations of the density in coincidence with particular events like ELMs or pellets. To overcome this difficulty several methods can be used, which fall mainly in two general categories. The first category includes approaches that use only the interferometric data. The second class of solutions includes methods based on the Faraday rotation or Cotton-Mouton effects that do not suffer from the fringe jump problem.

1. CORRECTION METHODS BASED ON THE INTERFEROMETRIC DATA

The most effective correction algorithm based on interferometric measurements exploits the two different wavelengths (“colours”) used in the lateral channels (fig.1, lines of sight no 5 to 8).

1.1 TWO COLOURS CORRECTION METHOD FOR THE LATERAL CHANNELS

In order compensate for the effects of the vessel movements (vibrations and others), the lateral channels use the typical two colours interferometry [3]. The two lasers are DCN (main laser, wavelength 195μm) and an alcohol one (compensation laser, wavelength 118μm) that, with the corresponding phase measurements correctly combined together, provide both the plasma density and the laser beam’s path length variation (vibration signal). The presence of fringe jump events, which correspond to an incorrect number of 2π rotations (fringes) in the measurement of the phase of the laser light, can be detected analysing the laser beam’s path length variation at 2 consecutive times. In the presence of fringe jumps the change of the vibration signal exceeds a given experimental limit. In this way the occurrence of fringe jumps can be detected and their magnitudes (number of fringes) derived from the requirement that the variation of the vibration signal be below a certain limit [4]. In general this method gives satisfactory results, particularly for fringe jumps due to ELMs or sawteeth (example in figure 2), but is not very effective in the presence of pellets. In the latter case the period in which the signals are lost is too long and the above mentioned limit on the residual vibration can introduce an error in the choice of the number of fringes. Using the method in discharges with type III ELMs, the proper density is recovered in at least 80% of the cases.

1.2. METHODS BASED ON INTERFEROMETRIC DATA FOR THE VERTICAL CHANNELS

For the vertical channels, for which the second colour is not available, one reasonable alternative consists in reconstructing the entire density profile, using only the chords not affected by fringe jumps, and then calculating the rest of the line integrals. The latter are good enough to yield the magnitude of fringe jumps by comparison with their measured counterparts, while the precise times of occurrence of fringe jumps are best obtained by looking at the difference between corresponding vertical and lateral chords directly at consecutive times. Fringe jumps cause this difference to exceed an experimentally found value, revealing their presence. On the basis of only the four lateral channels, corrected with the method described in the previous section, the plasma density profile is reconstructed assuming constant density on the iso-flux surfaces [5]. The internal flux surfaces are described in the usual parametric form which depends on quantities deduced in real time from the external magnetic measurements only. On the magnetic topology interferometric data is then inverted with a best-fit method. After that, the line-integrated density of vertical chords is calculated from the profile in order to remove the fringe jumps from the measurement. Figure 3 illustrates the method. The uncorrected experimental signal, the simulated line density and the output of the real time correction algorithm are compared, showing the quality of this solution. This approach is feasible in many cases even if, for very high density (more then 12×10^{19} m^{-2}), the uncertainty can reach the order of one fringe. Moreover it must also be mentioned that the reconstructed density involves an error of about 10% and therefore this approach is sufficient for real time purposes but not for off-line data analysis. This method performs very well in the case of fringe jumps due to ELMs and is also quite effective in the case of pellets (if the lateral chords are available). The computing time consumption is around few milliseconds, which is in general sufficient for many experiments requiring the density in real time.

If a faster technique is wanted, a different approach can be adopted, based only on the direct comparison between vertical and lateral channels, normalised to the line of sight length, which is available at JET on a suitable time scale. For real-time purposes, the vertical chords 2, 3 and 4 can be compared with the lateral 7, 8 and 5 respectively. Using also an appropriate geometrical factor to take the plasma shape into account, this approach allows the identification of both time and magnitude of fringe jumps. The time resolution of one millisecond is recovered with this solution.

This second approach is very effective for channel 3 but less for channel 2, since the effect of the changing profile shape is more pronounced for this channel. For channel 4 this solution gives better results than the former method.

4. CORRECTION METHODS BASED ON THE FARADAY ROTATION AND COTTON-MOUTON EFFECTS

The correction of chord 4, for which all previous methods do not perform well, can be performed using the polarimetric measurement of the Faraday rotation, since at the plasma edge the poloidal field is known from the external pick up coils and available in real time. The Faraday rotation $\Delta\Psi$ is given by the following relation:

$$\Delta\Psi = c \int_l n_e(l)\, B_{\parallel}(l)\, dl \qquad (1)$$

where $B_{||}$ is the poloidal field along the line of sight, n_e the electron density and c a coefficient. Channel 4 is the most external chord (apart from channel 1 which is out of the plasma in many cases) and therefore the poloidal field can be approximately treated as constant along this line of sight. In this approximation the polarimetric measurements can produce an estimate of the density for channel 4:

$$\Delta\Psi = c\bar{B}_{||} \int_{l} n_e\,(l)\,dl \; = c\bar{B}_{||}\, N_e \rightarrow N_e = c\bar{B}_{||}/\Delta\Psi \qquad (2)$$

The line-integrated density N_e derived in this way for chord 4 can be used successfully for both the detection of fringe jumps and their correction. It has been doublechecked that the error due to the constant profile approximation does neither affect the identification nor the correction of fringe jumps. At the moment, the main limitation of the method resides in the time resolution of the polarimetric measurements, which is often insufficient to correct the fringe jumps caused by pellets.

The Cotton-Mouton effect, being proportional to the square of the toroidal field in JET geometry, could also provide an alternative way to determine the vertical line integrated densities. The toroidal field, being constant along the vertical lines of sight, can be extracted from the integral:

$$\Phi_{CM} = k \int_{l} n_e\,(l) B_T^2 N_e = k B_T^2 N_e \qquad (3)$$

The potential of this method is under investigation: The signals suffer from mechanical problems (low frequency vibrations) which affect the optical system and make the measurement difficult to interpret at the moment [6].

REFERENCE

[1]. M. Riva et al, Proc. 22th Symp on Fusion Technology (SOFT), Helsinki, Finland (2002)

[2]. G. Braithwaite et al, Rev. of Scient. Instrum. **60** (9), September 1989, 2825-2834

[3]. I.H. Hutchinson, Principles of plasma diagnostics, Cambridge University 2003

[4]. P. Innocente et al, submitted for publication to Rev. of Scient. Instrum.

[5]. L. Zabeo et al, Plasma Phys. Control Fusion **44** (2002) 2483-2494

[6]. K. Guenther, 4 th Meeting of the ITPA Topical Group on Diagnostic, Padua, Italy, 17-21 February 2003.

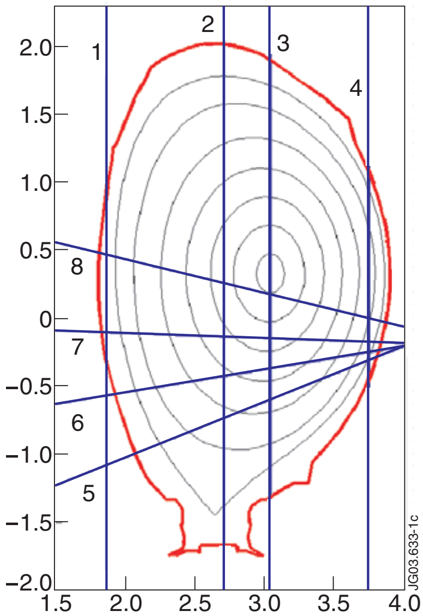

Figure 1: Lines of sight of JET interferometer/polarimeter

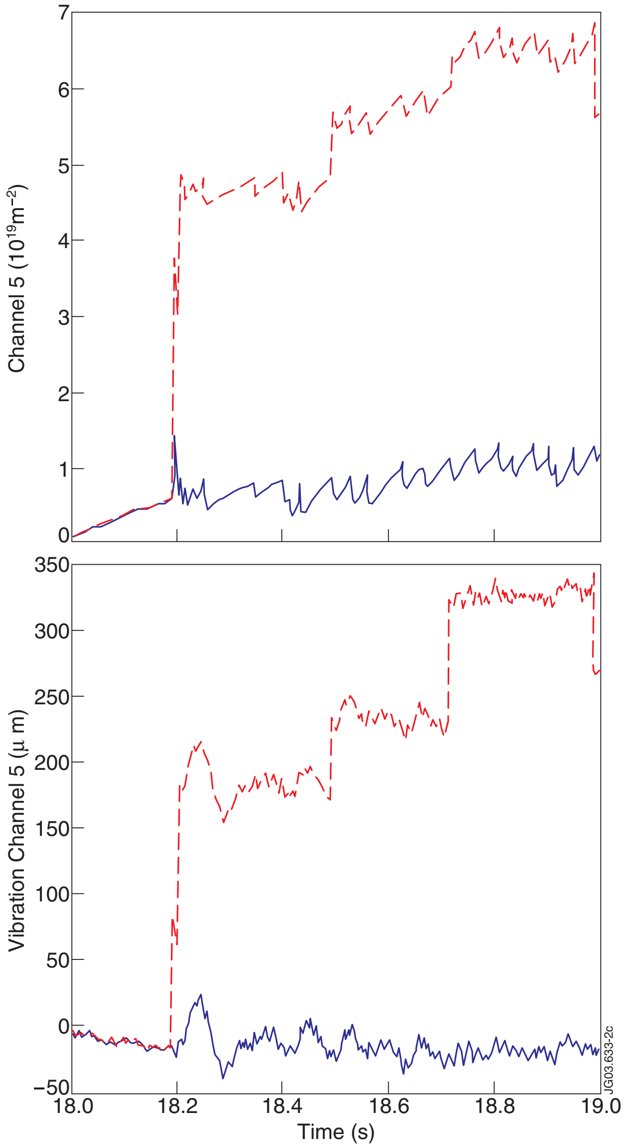

Figure 2: Density and vibration not corrected (red dashed line) and corrected (blue solid line) for Pulse No: 58126 channel 5.

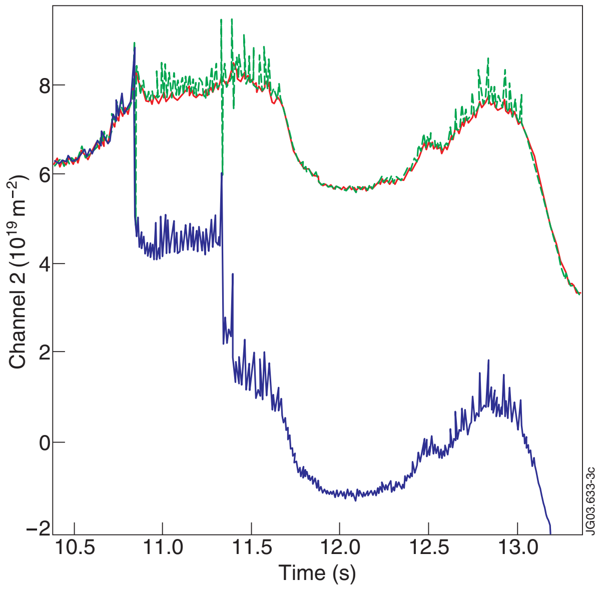

Figure 3: Non-corrected density (blue solid line), density simulation (red dashed line) and corrected density (green dash-dot line) for Pulse No: 58474.