ELECTRON DENSITY PROFILE MEASUREMENTS BY MICROWAVE REFLECTOMETRY ON TORE SUPRA

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INTRODUCTION

The proposal of this paper is a contribution for developing reflectometry diagnostic for electron density profile measurements as routine diagnostic without manual intervention as achieved at JET (1). Since density fluctuations seriously perturb the reflected signal and the measurement of the group delay, we described a method to overcome the irrelevant results with the help of an adaptive filtering technique.

EXPERIMENT

On the tokamak TORE SUPRA, three broad band O-mode reflectometers are installed (2). They cover the frequency domains 25-35, 35-50, and, 50-75 GHz and measure electron density profiles in the gradient region for densities between 0.8 to 6.8 10^{19} m^{-3}. The plasma is probed along the horizontal axis at the mid plane of the torus in order to minimise refraction effects. It is used transmitter/receiver antennae and homodyne detection system. BWO sources can be swept in 1 ms every 2 ms. The whole set up is located outside the vacuum vessel. The detected signal is then function of the phase difference between the wave reflected by the mica sheet at the end of the antennae and the wave reflected by the plasma cut-off layer (fig. 1).

DATA ANALYSIS

The position rc of the plasma cut-off layer is given by:

$$r_c(F) = \frac{c}{2}\int_0^F \frac{\tau(F)}{\sqrt{F^2-f^2}}\,df$$

determination of the group delay $\tau(F)$ is achieved by performing FFT of the signal. In order to follow the evolution of the group delay as a function of the frequency, sliding FFT analysis is done over reduced frequency intervals (assuming the stationarity of the signal over the integrating frequency interval). The group delay is directly extracted by taking the maximum of the spectra between 4 and 15ns (where the plasma cut-off layer experimentally remains on TORE SUPRA). Linear interpolation between points is made for profile inversion (fig. 2). Before each pulse operation, reflected signal from the back wall is used to subtract spurious reflections occurring along the line (couplers, antennae ...) whose propagation length may be comparable to plasma cut-off distances. The lowest frequency being 25 GHz, assumption about the edge need to be done in order to solve the Abel inversion integral. Frequently, a linear density profile decreasing to zero at the lcfs may be reasonable. Nevertheless, a better evaluation of the edge density (fig. 3) can be obtained with the help of the integrated density given by the interferometry diagnostic by minimising the difference:

$$n_l\text{interf.} - \int n_e\text{reflec.}\,dr$$

DENSITY FLUCTUATIONS

The advantage of such FFT analysis is to see how the reflected signal is affected by the density fluctuations of the plasma. On figure 4, we show an example of locally turbulent plasma obtained in high density conditions, and, group delay information is totally lost between 35 and 42 GHz. It seems that the apparition of spurious peaks is rather due to a scrambling of the phase, than to an attenuation of the amplitude of the reflected wave. Conditions in which plasma turbulence do perturb reflectometry signal or do not, is strongly dependent on density and temperature of the plasma, i.e., reflectometry signals at low density and high temperature exhibit low perturbation, and, current drive heating generally worsen the situation (fig. 5). MHD activity has been a well identified perturbation to reflectometry signal since the reflection of the microwaves is very sensitive to low wave numbers turbulence. However, the above conditions do not necessarily relate with such turbulence, since microturbulence also increases with density.

ADAPTIVE FILTERING TECHNIQUE

As we plot the group delay versus frequency one can observe jumps in the measurements. At this stage, data are fit with a polynom of order three, getting rid of the wrong points. This fit is used as the centre guide of a filter around which a restricted group delay interval is set in order to check again the maxima into the FFT spectra, this way the right peak can be better isolated, or, by default, interpolated. The computational calculation loops with a progressive reduced group delay window starting from 1.5 ns to 0.5 ns and the polynomial fit being each time recalculated (fig. 6) and behaves as an adaptive filter. In situation where signal is too perturbed the fit generally fails.

CONCLUSION

Progress still need to be done in order to clarify the role of the plasma density fluctuations to propagation and reflection of the microwaves. But now, density profiles given by reflectometry are now carried out routinely on TORE SUPRA and is now part of the common data base. Program, written in matlab, allows profile calculation between shots. Accurate profiles are estimated for about 70% of the shots.

REFERENCES

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(3) F. Nunes, J. Leitao, M.E. Manso: Proc. of the 20th EPS Conference Vol. 17C, part III p.1099 (1993).

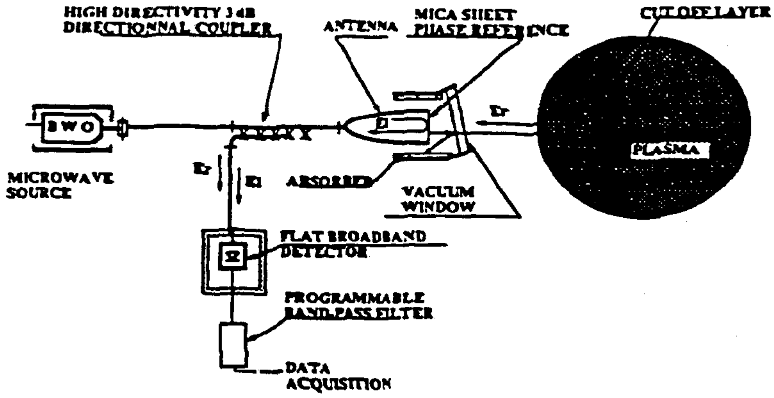

Fig. 1: Schematic diagram of the reflectometer on TORE SUPRA

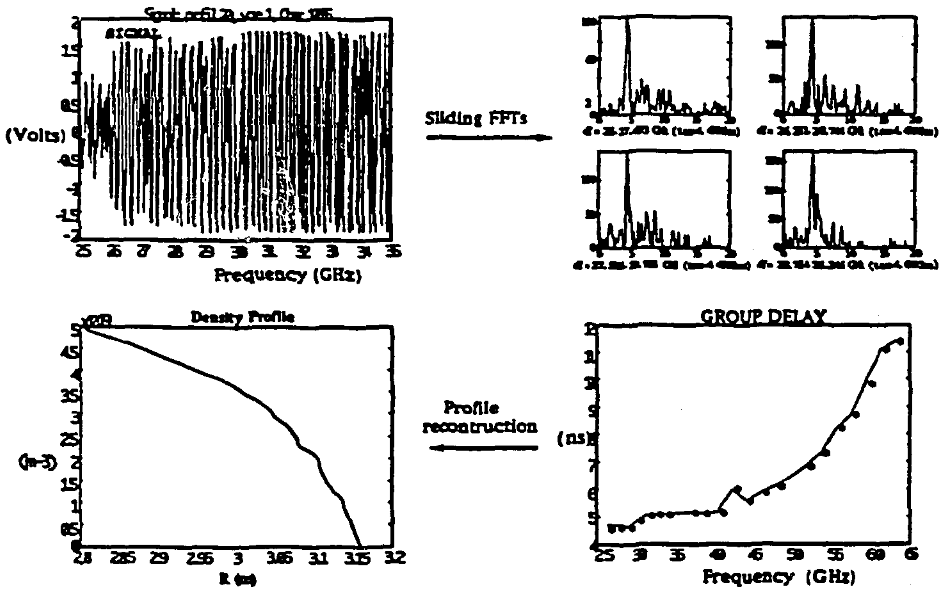

Fig.2: Data analysis by sliding FFT technique and profile reconstruction

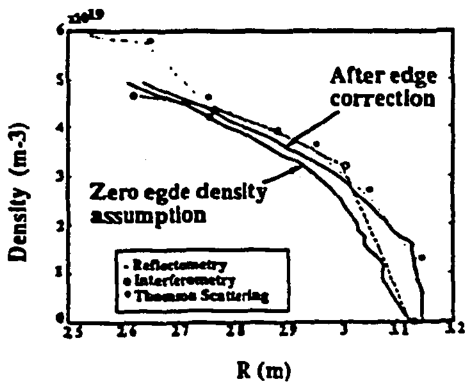

Fig.3: Density profile with edge correction and comparison with other diagnostics

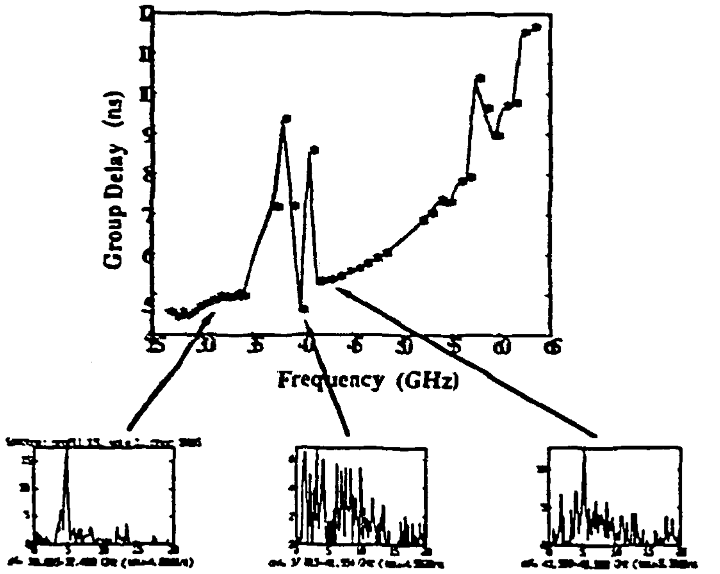

Fig. 4: Effect of density fluctuations on signal and group delay measurements

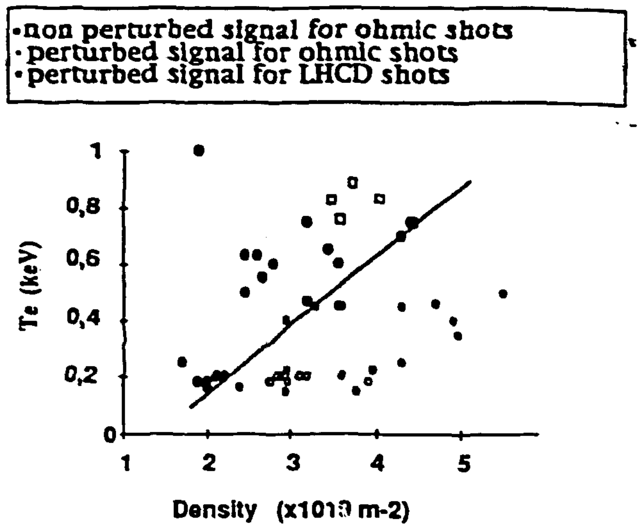

Fig. 5: Occurence of parasitic peaks as a function of the edge density and temperature

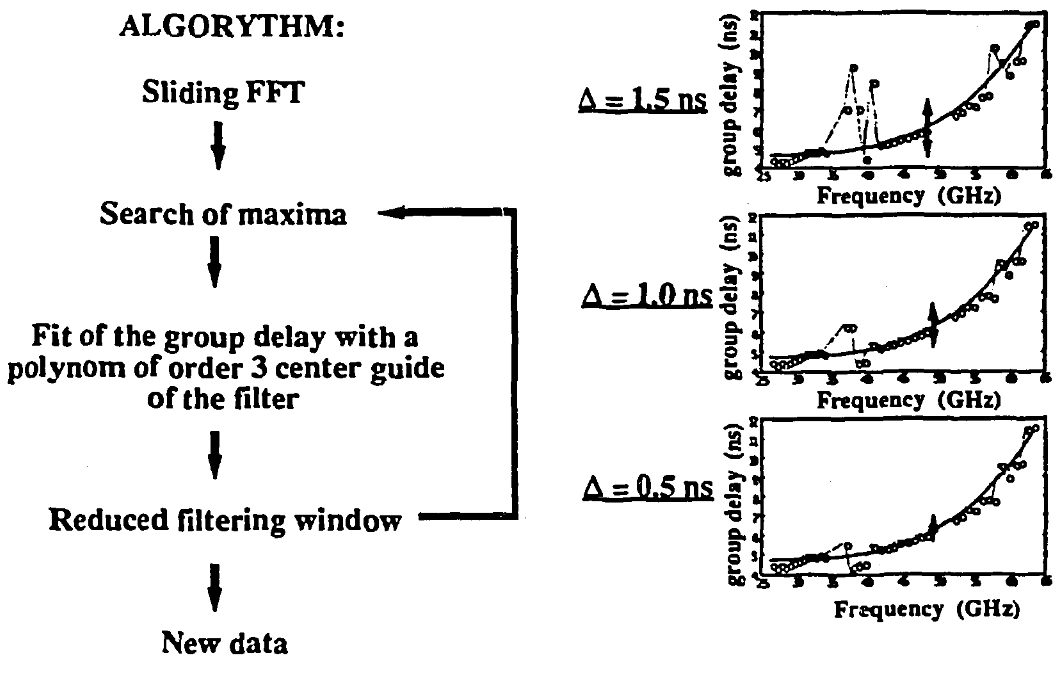

Fig. 6: Principle of the adaptive filtering technique for group delay data correction