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ABSTRACT.
Details are provided of a new fast data acquisition system that records RF data for a complete four-strap JET ICRH antenna array with sampling rates up to 250 kHz, triggered by the rapid increase in plasma Da emission intensity during an ELM. The coupling properties are deduced from the transmission line voltage amplitude and phase measured using 80dB directional couplers installed close to the antenna. Resistive and reactive components of antenna loading perturbation are reported during different types of ELMs and discharge magnetic configurations.

1. INTRODUCTION

Detailed knowledge of ICRH antenna array coupling characteristics during ELMs is valuable both for the design of ITER-relevant ELM-resilient matching systems and for understanding ELM phenomena [1]. JET plasmas offer an excellent opportunity for such studies given their abundance of various types of ELMs [2,3] and the availability of the JET multi-strap phased ICRH antenna arrays [4].

Previous measurements [5], using a PC-based fast data acquisition system connected to directional couplers located ~84m from the antenna, focused on the behaviour of individual antenna straps during “classic” JET discharges. The coupling resistance measured during an ELM comprised a fast (~150 µs) rise up to 8W followed by slow (~2-3 ms) decay, accompanied by an alternating and relatively small (±10 cm) strap electrical length change. This earlier system suffered from timing problems and limited accuracy and has now been upgraded.

2. NEW FAST DATA ACQUISITION SYSTEM

A new fast data acquisition system has been installed to provide RF data for a complete four-strap antenna array. It comprises 2×16 fixed channels, each providing up to 250kHz sampling rate and ~65000 points, triggered by the increase of plasma Dα emission intensity during an ELM.

The ELM-related coupling perturbations are deduced from the Antenna Transmission Line (ATL) voltage amplitude and phase measurements produced by accurate 80dB directional couplers installed close (~13m) to the antenna array (Fig.1). The resistive and reactive components of antenna strap loading are characterised respectively in terms of the coupling resistance $R_{IN\_ELM} = Z_0\,(V_{ATL\_F} - V_{ATL\_R})/(V_{ATL\_F} + V_{ATL\_R})$ and the electrical length $L = (P_{ATL\_F} - P_{ATL\_R})/(2\beta)$, where Z_0 is transmission line characteristic impedance (30Ohm) and b is the propagation factor. Because of the high VSWR in a mismatched ATL, the accuracy of coupling resistance measurement defined above quickly deteriorates at low loading between ELMs. For this reason, signals from the matched amplifier Output Transmission Line (OTL) are used additionally to calculate the coupling resistance during a low quasi-stationary loading $R_{BETWEEN\_ELM} = Z_0\,(V^2_{OTL\_F} - V^2_{OTL\_R})/(V_{ATL\_F} + V_{ATL\_R})^2$ and the generalised coupling resistance in an ELMy plasma is estimated to be $R = R_{BETWEEN\_ELM} + \Delta_{RIN\_ELM}$.

It is also worth noting that the JET A2 antenna is a complicated system of coupled resonant loops and a comprehensive description requires an advanced formalism (e.g. [6]). The approach described above is a traditional simplification aimed mainly at facilitating the matching analysis. Care needs to be taken in extrapolating the results to other antennas and deductions of coupling physics.

3. STRAP COUPLING DURING DIFFERENT TYPES OF ELMS

The general features of coupling resistance changes (Fig.2) are consistent with previous observations [5]: a fast increase up to 8-9W followed by a slow and highly variable decay. The electrical length behaviour, however, was found to be both quantitatively and qualitatively different: higher (up to ~40cm) perturbation magnitudes were detected with the length predominantly decreasing.

The response to ELMs within the array depends on the array phasing and is not particularly sensitive to frequency in the 28-51MHz band. The pair of straps which are close to the antenna central septum (septum straps) typically demonstrate smaller coupling perturbations compared with the outer pair (limiter straps). This can be explained by the different strap and feedthrough design.

No differences between the coupling perturbations induced by similar ELMs were found during the full array operation and the single strap operation, which indicates that the strap cross-talk is not likely to play a significant role in ELM coupling.

Although "big solitary" Type I ELMs produce the largest registered coupling perturbations, "small frequent" ELMs, including Type III ELMs can also cause substantial coupling resistance changes, which has strong implications for the RF plant matching. In general, the relationship between the level of Da activity and coupling perturbations' magnitude and temporal behaviour is not straightforward. Short time- scale (≤100 ms) H-L-H mode transitions, occasionally accompanying ELMs, were found to produce noticeable coupling resistance changes, which can contribute to and partly explain the coupling behaviour following an ELM (Fig.2).

4. COUPLING PERTURBATION DEPENDENCE ON PLASMA MAGNETIC CONFIGURATION

Figure 3 shows that the plasma magnetic configuration affects the magnitude of ELM-induced strap coupling resistance and electrical length perturbations. The analysis of max(DR) and max(DL) values in a series of shots with "similar" Type I ELMs shows that the perturbation magnitude increases with plasma triangularity and tends to decrease with antenna-plasma separation. The first dependence partially explains the discrepancies with earlier "low-triangularity" results [5] and implies an unfavourable scaling for ITER. The second should be scaled for ITER with care, as the larger outer gap also strongly reduces the coupling during the period between ELMs.

CONCLUSIONS

A new fast data acquisition system measures JET ICRH antenna array loading perturbations and fast RF plant responses during ELMs. The results have contributed to better understanding of ELM and ICRH physics and have helped to identify problems relevant to the design of ITER-oriented antennas and matching systems.

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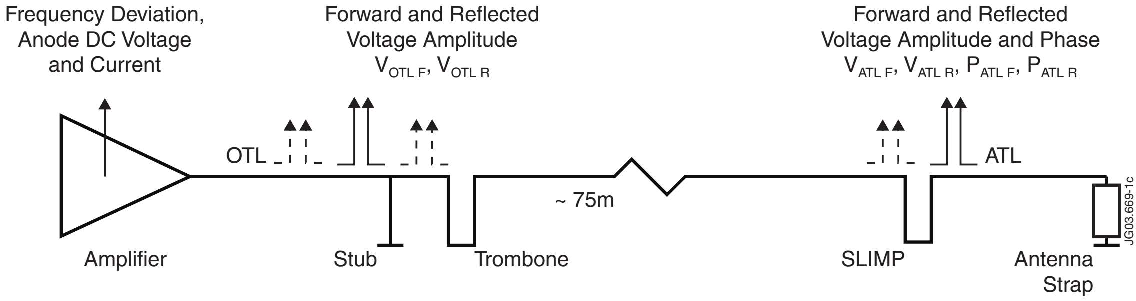

Figure 1: Schematic representation of fast data acquisition pickup points location and signal names.

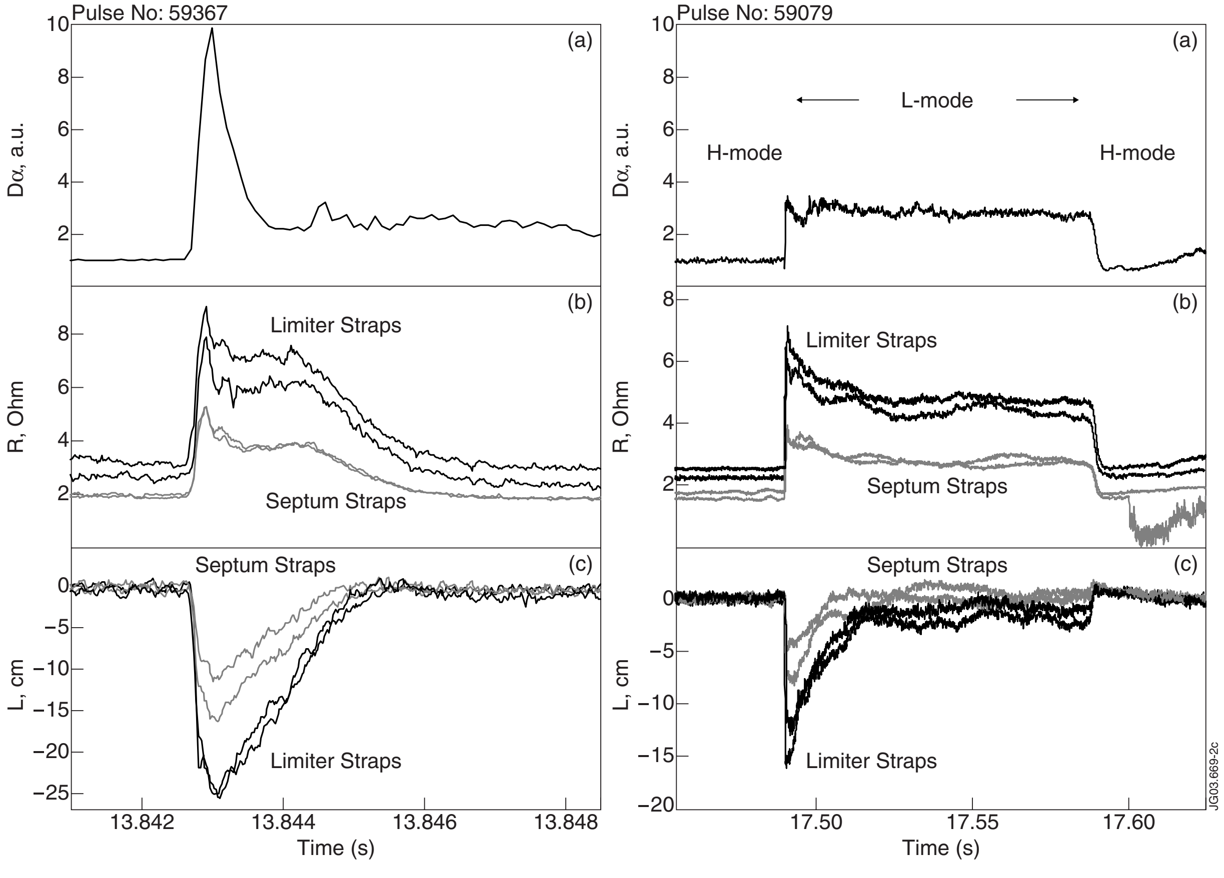

Figure 2: Temporal behaviour of strap coupling perturbations during a big Type I ELM (left) and a small ELM, accompanied by an H-L mode transition (right): (a) - Dα signal, (b) - coupling resistance and (c) - strap electrical length change. The different traces on plots (b) and (c) correspond to four straps of JET antenna array with grey shade used to denote the inner straps located close to the antenna central septum. Both discharges correspond to operations at f=42.1MHz and [0π0π] array phasing.

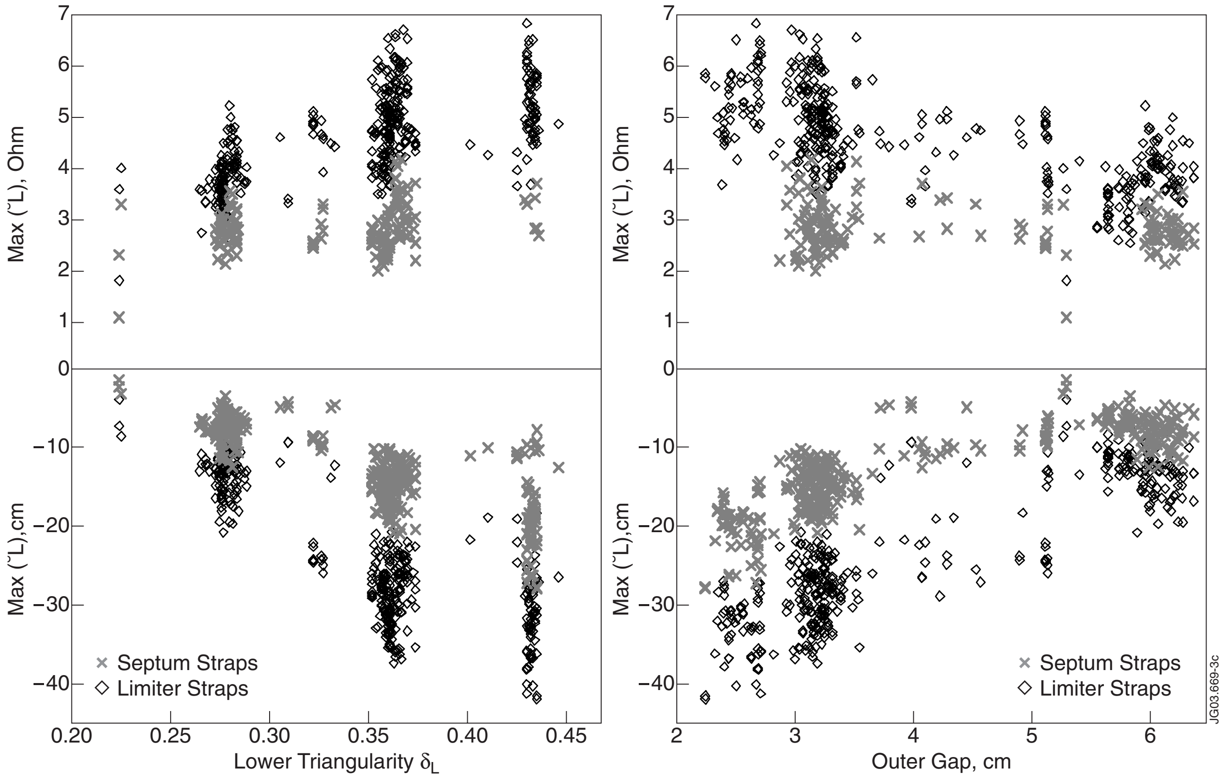

Figure 3: Dependence of strap coupling resistance and electrical length perturbation magnitudes on plasma lower triangularity (left) and outer gap (right). Data from ~55 pulses with the same RF frequency (f=42.1MHz) and array phasing [0π0π]. "Similar in magnitude" Type I ELMs are selected by choosing ELMs with mid-plane Dα signal changes in the range of 0.8-1.5V.