Suppression of Coherence Effects in the Measurement of Mmwave Absorption in the JET Plasma

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1. INTRODUCTION

The pumped divertor(1) is a major upgrade for the JET tokamak. Its purpose is to control the influx of impurities into the plasma and minimize the heat loading on the target tiles. The plasma parameters in the divertor region, low electron temperature, T_e, (10-100 eV) and high electron density, n_e, ($\sim 10^{20}$ m^{-3}) are very different from those of the bulk plasma. Electron cyclotron emission (ECE) cannot be used to measure local T_e because of the resulting low optical depth, τ. However low τ makes the measurement of electron cyclotron absorption (ECA) feasible(2)(3). The absorption is directly related to the local n_eT_e product.

The technique chosen to make this measurement must overcome a variety of problems: high background ECE from the bulk plasma, poor access for antennas, a 50 metre distance from the instrument to the plasma and coherence effects from the microwave source. Moreover, the instrument must be tunable over a 35 GHz bandwidth, which for a given plasma discharge is fixed somewhere in the range 120 to 240 GHz depending on the magnetic field value.

2. DIAGNOSTIC TECHNIQUE

The requirements of covering two waveguide bands (WR6 and WR4) and overcoming the significant losses in the system (~45 dB) have led to a design based on two BWO sources. Each BWO can cover an entire waveguide band, has an output power >10 mW and can be rapidly tuned (< 1ms, full band). However the high temporal coherence of such a source can produce standing waves and trapped modes in the oversized waveguides used to transmit the radiation to and from the plasma. This can result in significant time and frequency dependence of the transmissivity of the system.

2.1 SUPPRESSION OF COHERENCE EFFECTS

Waveguide discontinuities, such as oversized E- and H- plane bends, tapers, antennas and windows, are the cause of the standing waves. The discontinuities can reflect or mode convert some fraction of the radiation, forming resonant cavities which result in a strongly frequency dependent transmission.

Trapped mode resonances, in which power is converted into higher order waveguide modes which are trapped and strongly absorbed in the cavity, can produce particularly severe effects. Small mechanical movements can shift these resonances significantly which would introduce spurious (non-ECA) absorption into the measurement.

We are developing a swept frequency interferometer technique for suppressing these coherence effects. The method relies on a very linear sweep of the source frequency which generates a constant beat frequency at the detector by interference between radiation from a fixed reference arm and that from the plasma arm. The beat frequency, f_{IF}, is given by

$$f_{IF} = \frac{df}{dt} \cdot \frac{\Delta L}{c} \qquad (1)$$

where ΔL is the difference in length between the plasma arm and the reference arm.

Any radiation that is reflected between two discontinuities in the plasma arm will have taken a longer path length to the detector and will generate a displaced beat frequency when it beats with the reference arm (a ghost beat). By making the reference arm shorter than the plasma arm, all ghost beats will be displaced to frequencies above f_{IF}. The frequency separation of the ghosts from f_{IF} is given by

$$f_{ghost} - f_{IF} = \frac{df}{dt} \cdot \frac{2\delta L - \Delta L}{c} \qquad (2)$$

where δL is the effective distance between the two discontinuities. Assuming a sweep rate of 30 GHz/ms and ΔL of 1m, f_{IF} is 100 kHz. By separating bends, tapers and windows with at least 1 m (δL>1m) of straight waveguide, the ghost beats will lie at least 100 kHz above f_{IF}. They can then be eliminated from the detected signal by filtering. Furthermore, the trapped mode resonances are suppressed, because the rapid frequency sweeping prevents the phase matching required for resonance.

The transmission can be obtained by ratioing the detected signals measured with plasma (during the discharge) and without plasma (before the discharge).

2.2 THE PROTOTYPE INSTRUMENT

Initial experiments have been aimed at proving the principles of the technique. A test instrument has been made with a 10 m oversized (S-band) waveguide arm and a quasi-optical reference arm. A varactor tuned Gunn diode source has been linearised over a 1 ms sweep from 86 to 92 GHz. To generate large standing waves, a cavity circuit was added to the waveguide arm using an in-waveguide beamsplitter. The beat signal with the cavity installed is shown in Fig 1. The power spectra of the beat signals, I(f), with and without the cavity arm is shown in Figs 2 and 3. A 25 kHz top hat filter was applied in the frequency domain, as shown, and the time traces were reconstructed from the filtered spectra. Fig 4 shows the ratio of the modulation envelopes of the two filtered time traces. The modulation, around the expected value of 1, evident in Fig 4, is because the filtering process has not yet been optimized.

3. CONCLUSION

The swept frequency interferometer technique has been successfully implemented on a prototype instrument for the ECA diagnostic. On the basis of these results, the actual instrument is now being designed. This design and further results will presented at the conference.

The authors wish to thank Dr. Richard Wylde for many informative discussions and for contributions to the design of the quasi-optical reference arm used in this work.

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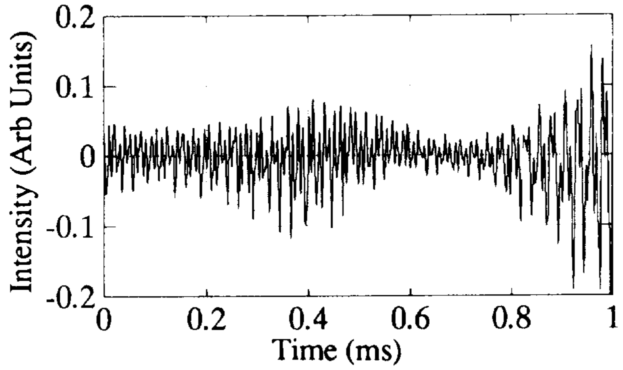

Figure 1: Time trace of the beat signal

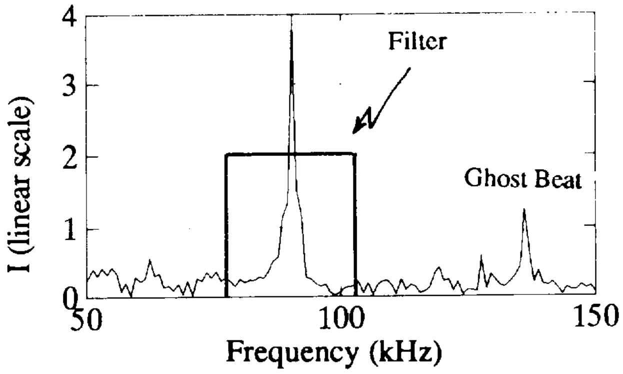

Figure 2: Power Spectrum of Beat with Cavity.

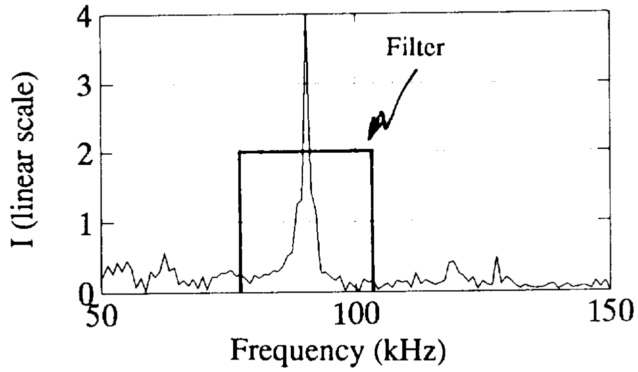

Figure 3: Power Spectrum of Beat without Cavity.

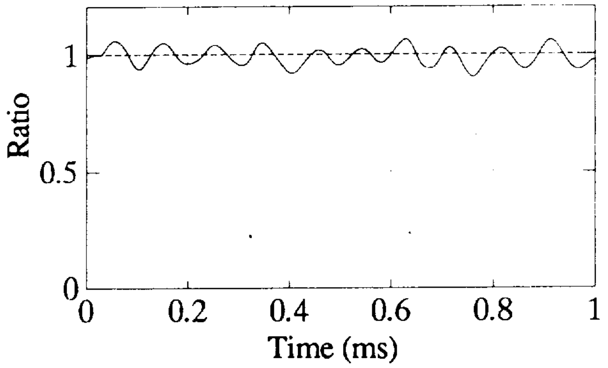

Figure 4: Ratio of the modulation envelopes of the reconstructed time signals