Absolute intensity calibration for ECE measurements on EAST

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Abstract

In this proceeding, the results of the in-situ absolute intensity calibration for ECE measurements on EAST are presented. A 32-channel heterodyne radiometer system and a Michelson interferometer on EAST have been calibrated independently, and preliminary results from plasma operation indicate a good agreement between the electron temperature profiles obtained with different systems.

I. Introduction

Electron cyclotron emission (ECE) measurement is one of the routine diagnostics in magnetically confined plasmas since the 1960s [1]. It provides the temporal evolution of local electron temperature with fairly good spatial and temporal resolution under certain conditions [2] and the information on the electron velocity distribution [3,4].

Technically, the ECE spectrum can be measured by using either optical or microwave method for the reason that the ECE in conventional magnetically confined plasmas is in the microwave range. The Michelson interferometer and the heterodyne radiometer systems are routinely used for ECE measurement in magnetically confined plasmas [5,6,7,8]. The Michelson interferometer has very wide frequency coverage, and the hardware is very simple and robust. Having high light throughput, the system can be easily calibrated. Poor spectral resolution and low temporal resolution are the weak points for the Michelson interferometer, while these are exactly the strong points of a radiometer system. However, the hardware of a radiometer is much more complex. Generally, the radiometer is cross-calibrated with the Michelson interferometer if it is available, or with other diagnostics like Thomson scattering.

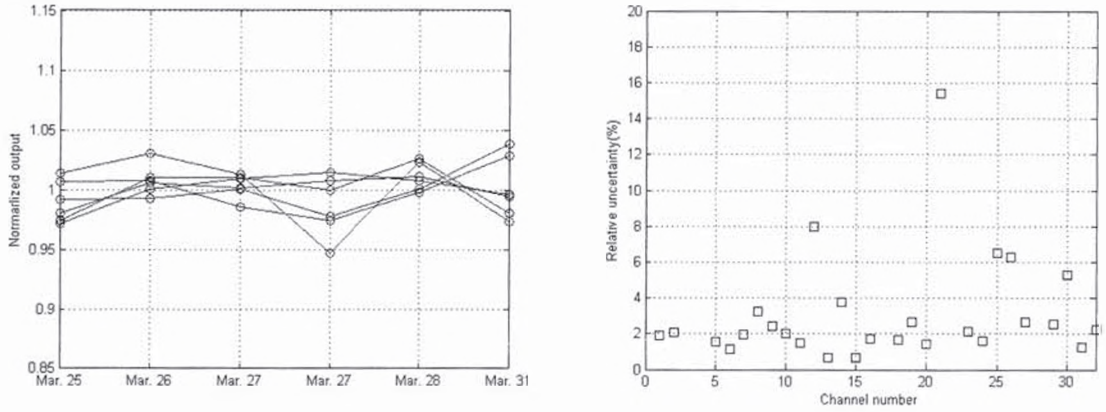
The different calibration strategies lead to the motivation of our work. First of all, an independent Te from ECE measurement is essential. The second motivation is to verify the independent intensity calibration for the radiometer system on EAST. It is also essential to validate the cross-calibration between the radiometer system and the Michelson interferometer, because the spectral resolution and the temporal resolution are so different for them.

Comprehensive ECE diagnostics have been commissioned on EAST [9,10,11]. This proceeding will focus on the in-situ absolute intensity calibration for a Michelson interferometer and a 32-channel heterodyne radiometer system on EAST. To validate the cross-calibration between a radiometer system and a Michelson interferometer, they were calibrated independently. Section II of this proceeding focus on the characterization of the systems and the calibration hot source. The in-situ absolute intensity calibration of the two systems is depicted in Section III. In Section IV, preliminary results from plasma operation are given.

II. System characterization

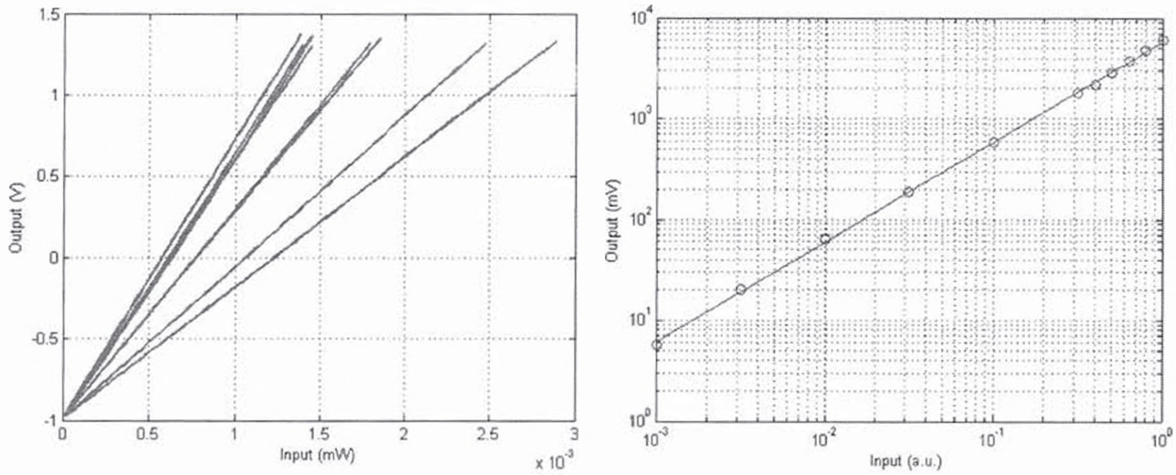
II.I. Stability test of the radiometer system

Before the in-situ absolute intensity calibration is performed, the systems were carefully and fully characterized. For the radiometer, the most concerned is the stability. The radiometer on EAST is placed in a laboratory with controlled temperature and humidity. The system sensitivity is monitored, by measuring the radiation of a hot source within one week. Figure 1(a) shows the variation of the normalized sensitivity within one week for some channels. As illustrated in Figure 1(b), the relative uncertainty for most channels is within 10%.



(a) (b)

Figure 1: (a) Evolution of the normalized sensitivity within one week for some channels of the radiometer system; (b) The relative uncertainty for all channels.



(a) (b)

Figure 2: (a) Linearity measurement results for the IF part (Channels 01-08) of the radiometer; (b) Linearity measurement results for the detector and electronics of the Michelson interferometer.

II.II. Linearity measurement

Linearity is another important issue, because the radiation intensity of the calibration source is weaker than the plasma emission by a magnitude of 4 to 5. Linearity is the precondition to do the extrapolation. For the radiometer system, the components were carefully chosen and arranged to achieve a good linearity. For the Michelson, the linearity is mainly determined by the detector and the electronics. Generally, it is very difficult to characterize the linearity of the RF part of a radiometer system. The IF part can be characterized by using a sweep source, and the results for some channels are shown in Figure 2 (a). The Linearity measurement results for the detector and electronics of the Michelson interferometer is shown in Figure 2(b). As the results show, the linearity is quite good for both systems.

II.III. Emissivity measurement of the calibration hot source

After characterizing the systems, the emissivity of the calibration hot source was measured. To obtain the emissivit, the hot source and another source with known emissivity were measured separately with the Michelson interferometer. In ECE community, the TK material with pyramidal shape is believed to be an ideal blackbody, and it is used in our case. The measured emissivity and the relative uncertainty for the hot source are shown in Figure 3.

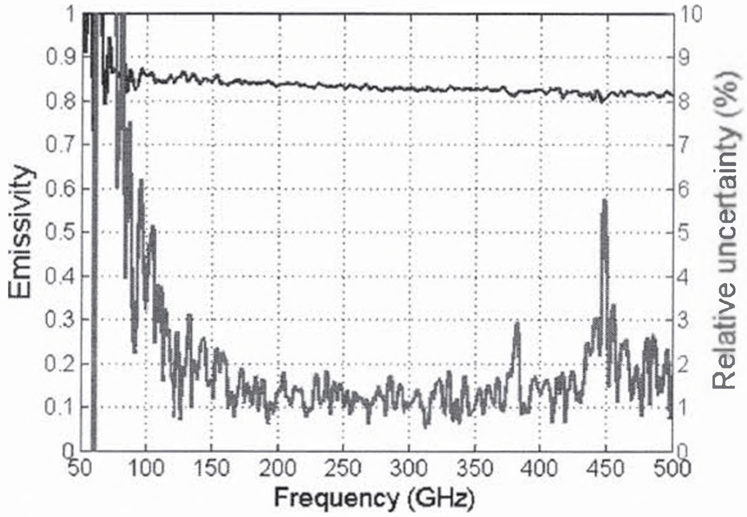
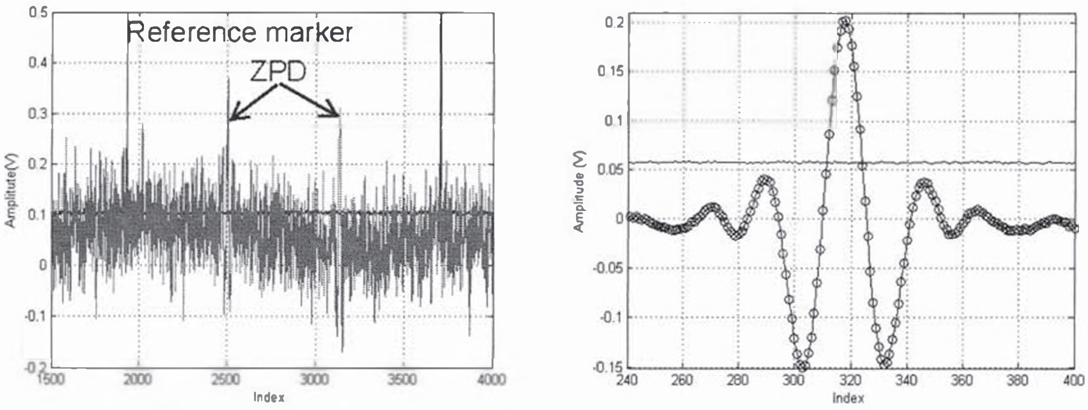


Figure 3: Measured emissivity and the relative uncertainty for the calibration hot source.



(a) (b)

Figure 4: (a) Original interferograms for one scan measured by the Michelson interferometer; (b) Averaged interferogram for 9000 scans.

III. In-situ absolute intensity calibration

After the systems were fully characterized, the hot source was placed inside the vacuum vessel for the final in-situ calibration. The radiometer and the Michelson interferometer were calibrated independently. The calibration strategies for them are slightly different. For the interferometer, the calibration was performed at a source temperature of 600 degrees, while different temperatures were used for the calibration of the radiometer system in order to reduce the deviation of the calibration factor.

Figure 4(a) is the raw data of an individual scan from the Michelson interferometer. The two peaks correspond to the zero-path-difference (zpd) where constructive happens for all frequency radiation. Because the gain is much higher than that for the plasma operation, the S/N ratio is bad. Therefore, every 9000 scans are averaged to obtain an interferogram as show in Figure 4(b). In total, 28 averaged interferograms were obtained, and consequently 28 spectra. The averaged spectrum (solid line) and the standard deviation (dashed line) are show in Figure 5.

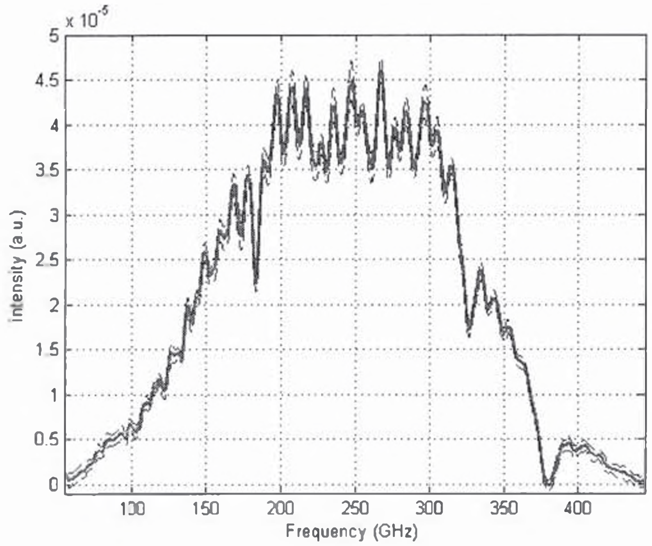
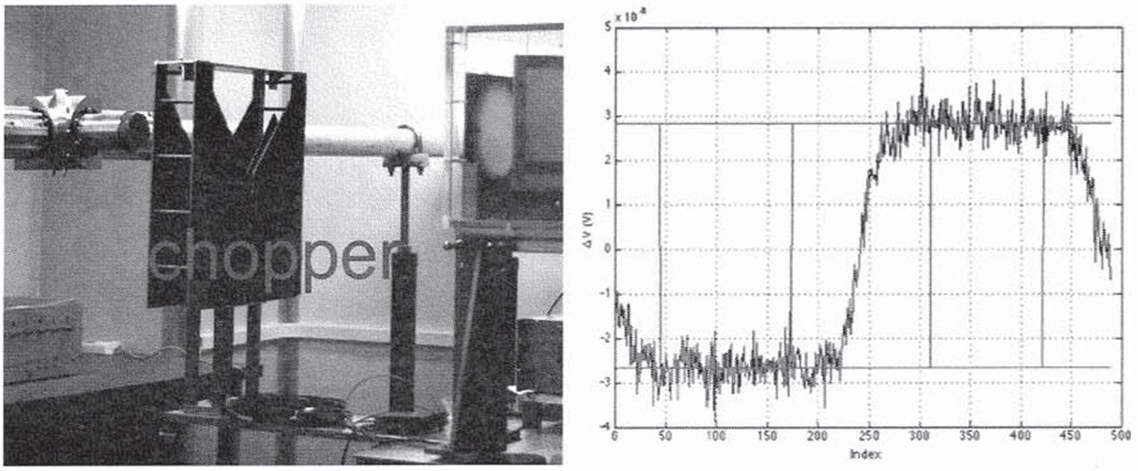


Figure 5: Averaged spectrum (solid line) and the standard deviation (dashed lines) for the calibration hot source from 28 individual measurements by using the Michelson interferometer.



(a) (b)

Figure 6: (a) Chopper adopted for ultra-weak signal detection; (b) Averaged data for one channel of the radiometer system.

Calibration procedure for the radiometer is shown in Figure 6. The input is modulated with a chopper as shown in Figure 6 (a), and the coherent averaged data for one channel is illustrated in Figure 6 (b). Figure 7 shows the outputs of one channel versus different source temperatures. The calibration factor is obtained by linear fitting.

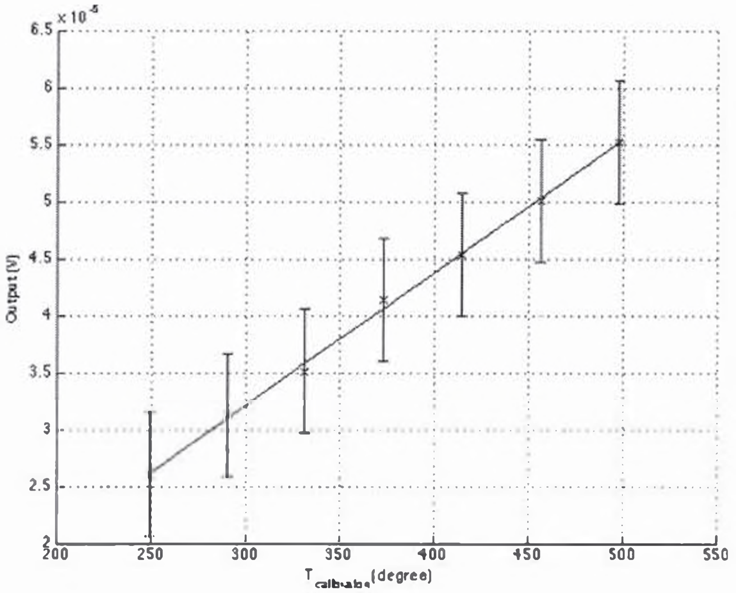


Figure 7: Calibration results for one channel of the radiometer system.

IV. Preliminary results for plasma operation

The 2014 EAST campaign started very lately, and there are only a few discharges with appropriate plasma parameters for ECE measurement. Figure 8 is the ECE spectra of EAST discharge 45273 at the time slice 2 seconds. The spectra were measured separately by the Michelson interferometer (red line) and the radiometer system (square), and there is a good agreement between them. The plasma current and line integrated density are separately 170 kA and $3\text{x}10^{19}$ m^{-3} for this discharge.

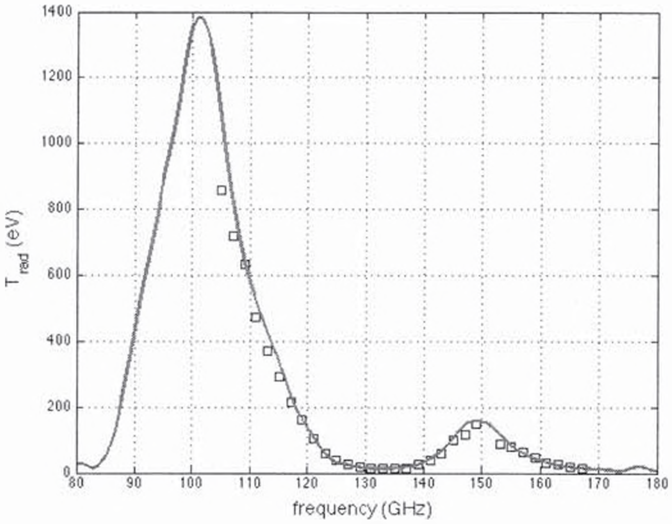


Figure 8: ECE spectra measured by the Michelson interferometer (red line) and the radiometer system (square), 2 seconds at EAST discharge 45273.

V. Summary

The Michelson interferometer and the 32-channel heterodyne radiometer system on EAST have been calibrated independently. Preliminary results from plasma operation indicate that the agreement of the electron temperature profiles measured by the two systems is fairly good.

Acknowledgements

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