# §4. Monte-Carlo Simulation for the Density Calibration by Microwave Reflectometry

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For confirming the effectiveness of the density calibration by the reflectometer based on the Bayesian estimation, a Monte-Carlo simulation is carried out. The calibration factor 'd' derived form the reflectometer measurement is simulated using a random function based on a Gauss distribution. We assume the reflectometer and the Thomson scattering measurements include no systematic error. First, $w_d$ is determined by a random value from the Gaussian distribution that is determined by the given standard deviation, then the calibration factor 'd' is determined from the random function of which standard deviation corresponds with the $w_d$.

We assume the worse situation as the calibration experiment, such that the derived factors are considerably scattered due to the measurement error caused by the reflectometer and the Thomson scattering diagnostics. The real value of calibration factor $C^T$ is assumed as 12. The result of the simulated calibration form the reflectometer is shown in fig.1 (a).

The calibration factors are derived from following formula, which is explained in the previous article ("Density Calibration Method by Microwave Reflectometry based on Bayesian Estimation")

$$C^T_{posterior} = \int_0^\infty xP(x|d)dx \quad (1)$$

$$w_{posterior} = \sqrt{\int_0^\infty x^2 P(x|d)dx - (C^T_{posterior})^2} \quad (2)$$

The estimated calibration factor $C^T$ using the eq.(1) is shown in the fig.1 (b). The calibration factor that is estimated from the simple average method is also plotted on the same graph. The horizontal line indicates the number of steps. One step corresponds to one modification of the calibration factor with one simultaneous measurement with the Thomson scattering measurement and the reflectometer.

We assume that the initial value of calibration factor $C^T$ is considerably different from the real value of 12 ($C^T_{prior}$=8). After a few steps (~ 15) of the improving calibration factor with the reflectometer, the $C^T$ converge to the close value of 12, and the calibration value is stabilized near the real value. In contrast, the calibration factors derived form the average method are far form the real value and not stabilized compared with the Bayesian method. The final value of the $C^T$ from the Bayesian method after the 50 steps is 12.1 ± 0.1.

Since these results depend on the random function, the results are confirmed through the repeated simulations by 100 times. The results of the probability histogram of the estimated calibration factors are shown in 1 (c) ,(d). Even in 10 steps case, 50 % of the modified calibration factors are improved within 5% of the real value. After 50 steps, 85 % of the calibration factors are improved within 2% of the real value. In contrast, the calibration factors which are improved within 2% of the real value after 50 steps by the average method is at most 25%. When a type of laser on Thomson scattering device is a high repetition Nd:YAG laser (10Hz), the 10-20 simultaneous measurements for the calibration is possible during one discharge. Consequently, expected number of discharges for the density calibration is below 10.

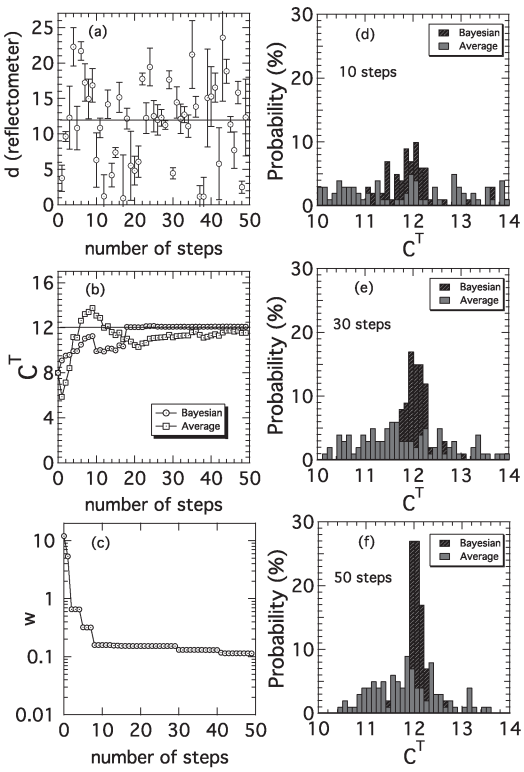


Fig. 1: Monte-Carlo simulation of Thomson density calibration by microwave reflectometry. (a)Simulation of estimated calibration factors from the random function based on the Gaussian distribution. (b) Estimated calibration factors $C^T$ from the calibration factors of (a) using eq.(1). Calibration factors that is derived from the average method is also shown in the same graph. (c) Standard deviation ( error bar ) of $C^T$. (d) Probability histogram of simulated calibration factor after 10 steps. Simulation is repeated by 100 times. Probability histogram using average method is also shown. (e) Probability histogram after 30 steps. (f) Probability histogram after 50 steps.