## §14. Phase Runaway Phenomena in Microwave Reflectometry

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Although microwave reflectometers have been used in many devices to measure density fluctuations, they have several problems in interpretation of obtained data. One of the problems is the phase runaway effect, which denotes the phenomenon that the measured phase moves unreasonably fast in one direction. In order to understand the problems, several types of reflectometer have been used on the JIPP T II-U tokamak. In this report, fringe jumps which cause the phase runaway and their effects are described.

Homodyne, heterodyne, and ultra-narrow band reflectometers are used. Phase runaway and rapid phase variation are observed with all systems, except with the homodyne system which can not measure phase. These phenomena are observed by both the O-mode launching system and the X-mode launching system. When the edge is measured, relatively slow phase runaway (mild runaway) is observed. The phase includes many fringe jumps ($2\pi$ phase jumps) (Fig.1). For faster phase runaway cases, it is difficult to identify fringe jumps in the running phase. The rest of this report concentrates on the mild runaway. In most fringe jumps, the amplitude of the reflected wave is well above the noise level during the jumps. Each fringe jump consists of a rapid phase jump by less than $2\pi$ and a slow phase variation. In other words, the fringe jumps appear in long time scale, but in shorter time scale, the amount of rapid phase change is not $2\pi$. These results imply that most of the fringe jumps are not caused by errors in the measurement system. Thus, the runaway is not the problem of measurement system, but it is a result of an interaction between microwaves and the plasma.

An algorithm to remove fringe jumps has been developed, so that the phase without runaway (corrected phase) is obtained (Fig.1). In this algorithm, stepwise phase variation is detected by convolving phase signals with kernels, which are stepwise functions with different time spans. The convolution shows peaks at the stepwise phase variation. The data larger than a threshold level are skipped, and then the phase is connected to get a continuous phase. The skipped data is filled with a data which is the original data without linear fringe jump components. About 5% of the data is skipped in the case of Fig.1. This algorithm has been applied to a mild phase runaway case, in which the plasma edge is measured. Almost all jumps are removed, and the time behavior of the corrected phase is similar to those of the major radius. Since the phase mainly represents the movement of the edge position, it is reasonable for the corrected phase to show a similar time behavior as that of the major radius. From theses facts, we can conclude that the mild phase runaway is caused by many fringe jumps, and that the runaway is not caused by a continuous phase change in one direction.

A power spectrum is a standard method to show the characteristics of fluctuations. Using the algorithm, we can distinguish the effect of fringe jumps from that of the residual fluctuations without fringe jumps. The power spectra of the phase with runaway and that without runaway are calculated. The former spectrum has much larger power in low frequency range, and the difference gradually decreases with frequency (Fig.2). Thus, low frequency components are affected by phase runaway.

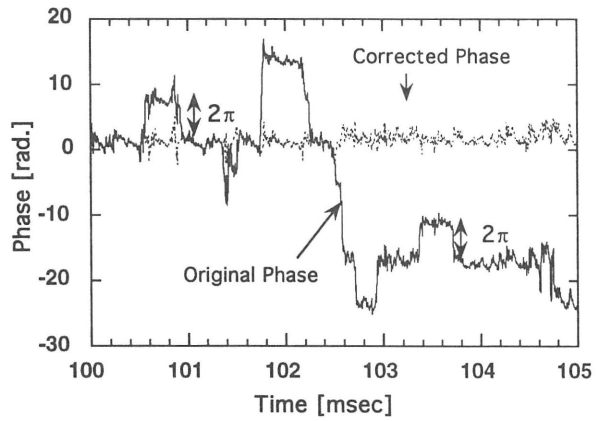


Fig.1 Measured (original) phase, and corrected phase by the algorithm.

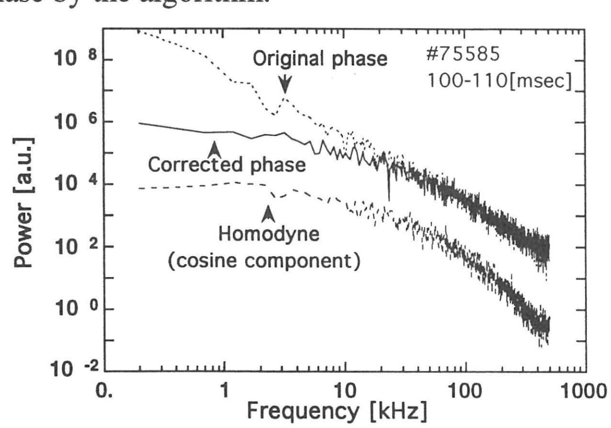


Fig.2 Power spectrum of original phase (with fringe jumps) and corrected phase (without fringe jumps). The spectrum of homodyne signal is also shown as a reference.