§27. Development of a Pulsed Radar Reflectometer for CHS Plasmas

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Pulsed radar reflectometry is one of the promising methods for measuring the radial density profile and density fluctuations with high temporary and spatial resolution. It could be useful for measurements at plasma edge (SOL, divertor) as well as for the core plasmas. This technique is based on time measurements of launched and received pulses.

A 3-channel pulsed radar system (51, 54, 57 GHz) has been designed for CHS. It is similar to that developed by RTP tokamak group [1]. The difference is that we multiplex 3 frequencies into single "mixed" pulse and split the received pulse with bandpass filters at IF stage. The advantage of this scheme is that we launch 3 different frequencies simultaneously and use only one local oscillator.

Due to the fluctuations, the amplitude of received pulses from the plasma could vary significantly. We use a Constant Fraction Discriminator (CFD) in combination with a Time to Amplitude Converter (TAC) to get the timing of received pulses. Although the CFD yields the timing independent of the pulse amplitude, deformation of the pulse shape in the plasma causes errors in the timing measurements by CFD. A numerical simulation has been done to estimate the CFD timing errors. We found that errors are negligible for pulse width longer than about 0.75~1.0 ns. To obtain a well-shaped launching RF pulse production we tested two types of fast switches (fast PIN switch from Millitech Corp., USA and varactor-diode fast modulator from Kharkov Institute of Radiophysics and Electronics, Ukraine). The minimum pulse width we can get with RF detector is 1.53 ns, and is 1.7 ns with heterodyne detection. Free space time-of-flight measurements have been done. The spatial resolution was 0.3 cm, which comes from the accuracy of TAC output reading. An accurate ADC could improve this spatial resolution.

Preliminary experiments with 1-channel system have been done in CHS to optimize the transmission line. 51GHz 1-channel pulsed radar reflectometer has been installed in CHS. The waves are launched into the plasma in the ordinary mode. The critical density is 3.2×10^{13} cm^{-3}. The transmitter is placed at the distance of about 5m from CHS. Detection part is placed close to the device (~1 m). A conical horn with a Teflon lens has been used for launching and receiving microwave pulses. The plasmas were initiated by IBW and heated by NBI. The maximum density is about 6.2×10^{13} cm^{-3}. Without plasma we clearly observe reflected pulse from the inner wall of the device. In these experiments we measured reflected pulses by a sampling oscilloscope, for which 10000 pulses are required to get a pulse shape. Figure 1 shows the comparison of the measured and calculated time delays as a function of maximum density. During the discharge time, at the low-density stage where $n_{e\,max} \le 0.5\times n_{critical}$, we could observe the reflected pulse from the inner wall. In this case, the system is operated as an interferometer. When the plasma density becomes $0.5\times n_{critical} \le n_{e\,max} \le n_{critical}$ the amplitude of the reflected pulse became very small, because of the refraction of the wave. When the density becomes higher than the critical density $n_{e\,max} \ge n_{critical}$ we observed the reflected pulse from the cutoff density layer. In this case the system is operated as a reflectometer. The measured data follow the calculated curve, but error bars are large. This comes from the strong amplitude modulation of the reflected signals and using of a sampling oscilloscope.

References
1) C.A.J.Hugengoltz, S.H.Heijnen, Rev.Sci.Instrum. 62, 1100 (1991)

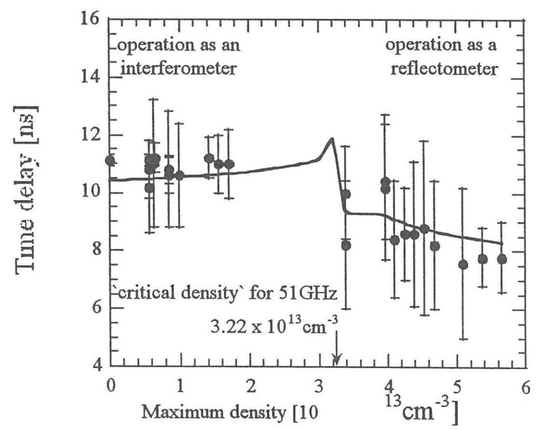

Fig.1. Comparison of measured (circles) and calculated (line) time delay as a function of maximum density. Parabolic profiles are assumed.