§4. Development of Multi-channel V-band Frequency Hopping Microwave Reflectometer for Density Fluctuation Measurement

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In order to measure the internal structure of density fluctuation, we have been developing a new type of reflectometer which is the broadband frequency tunable system and has the ability of fast and stable hopping operation. During a plasma discharge, the launching frequency increases step by step, which this operation is called as frequency hopping, and the cut-off position can be scanned in the wide area. One of the important issues of this measurement is the study of energetic particle driven magneto hydrodynamics instability. Recently, the system is upgraded from single channel to multi-channel.

The schematic of multi-channel frequency hopping V-band reflectometer system is shown in Fig. 1. A microwave synthesizer is used as a source with a low phase noise. The output frequency is easily changed by the external controlled signal. For the direct phase measurement, the single side band (SSB) frequency modulation is utilized. The source output is split into the probe and the reference signal. Two SSB modulators are used for the two spatial position measurements. Each SSB modulator driven by 220 and 2.5 MHz quartz oscillators shifts the frequency of the probe signal for the heterodyne I-Q detection. The output frequency components are shown in Fig. 2. Here, the carrier frequency is 14 GHz. The output frequency is quadruple followed by an active multiplier to bring the launching frequency up to 50-72 GHz (V-band). The modulated microwaves launch from the outboard side along inverse the major radius direction on equatorial plane. The polarization of launching wave is set on the extraordinary mode and the right-hand cut-off layer is used as the reflected surface. Each reflected wave is received and mixed with reference wave and each intermediate frequency (IF) signal is amplified and discriminated by each BPF, then led to I-Q detection.

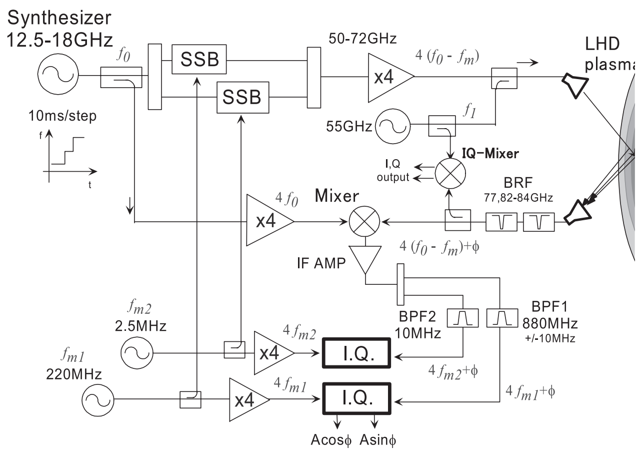

Fig. 1. Schematic of multi-channel V-band frequency hopping microwave reflectometer. f_0 is carrier frequency (12.5-18GHz), f_{m1} and f_{m2} are modulation frequencies (220MHz and 2.5MHz), and ϕ is plasma fluctuation component.

Example of preliminary LHD experiment is shown in Fig. 3. Figure 3 shows the reflectometer output, the hopping carrier frequency, and the frequency spectra of two IF components. We can see coherent frequency component of around 90 kHz in both signals and the distribution of the fluctuation power is shifted with the probing frequency difference.

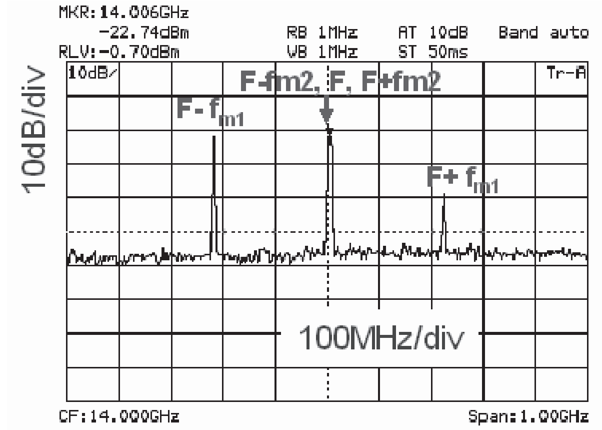

Fig. 2. Frequency spectrum of the combined signal of two SSB modulator outputs in the LSB operation. The carrier frequency (F) is 14.0 GHz and the modulated frequencies are 220 MHz (fm1) and 2.5MHz (fm2).

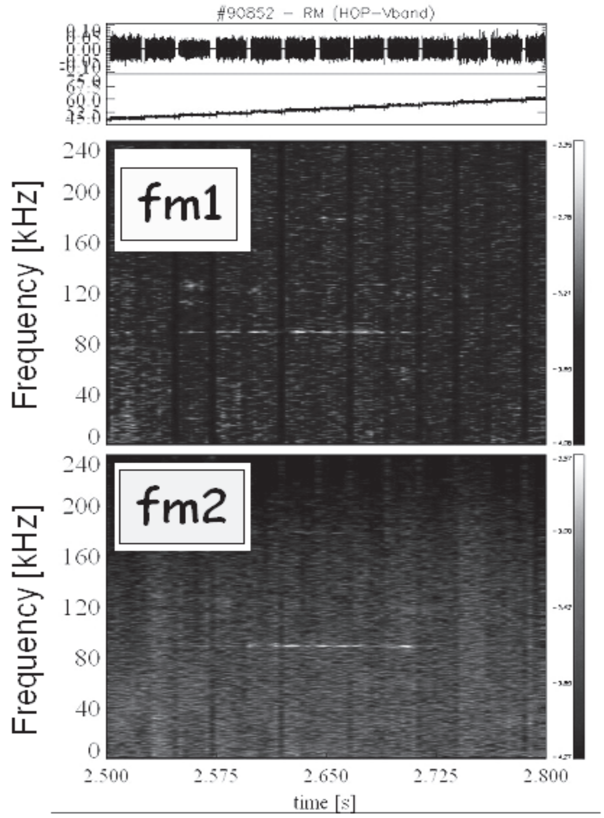

Fig. 3. Example of the plasma experiment. Temporal behavior of reflectometer signal (top), hopping carrier frequency, and frequency power spectra of both detector outputs of f_{m1} signal and f_{m2} signal.