§11. Development of Advanced Microwave Devices and Application to LHD Diagnostic Systems

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Microwave to millimeter-wave diagnostics have been well developed by the advancement of system components using integrated circuit and micro-fabrication technologies and of computer technologies. Microwave imaging is one of the methods to visualize dynamic behavior of plasma fluctuations [1]. The purpose of this research is to develop the components for these diagnostics, and apply combined systems to the LHD experiment.

In microwave imaging system, a quasi-optical band stop filter (notch filter) is required to prevent spurious electron cyclotron heating power and thus to protect array detectors from damage or saturation. The development of notch filters with good performance is one of the key issues in the ITER microwave diagnostics. There are following requirements for this notch filter: i) it must cover the whole area of beam diameter of array detectors, ii) it should be relatively insensitive to the angle of incidence, iii) it is required to exhibit low loss in the pass frequency band in addition to large rejection at the notch frequency resulting in a requirement for high Q.

This year we have designed and fabricated frequency selective surface (FSS) filters with notch frequency of 154 GHz, since new gyrotron with its frequency is to be installed in the next campaign of the LHD experiment. It is designed by an electromagnetic field software, MW Studio (CST Co.), using the period moment method (PMM). The designed shape is square loop structure and is fabricated by etching process.

The rejection of FSS notch filter is typically 30 dB [2-3]. The rejection more than 50 dB is preferable to eliminate spurious ECRH power and to protect detectors. In order to satisfy it we try to use two-to-three layer of filters with same performance. The characterization of the filters is performed by using an apparatus shown in Fig. 1. A Gunn oscillator and multiplier are used as a 135-155 GHz source. A sub-harmonic mixer produces a signal with intermediate frequency (IF) between incident frequency (f_i) and ten times local frequency ($10f_l$), which is fed to a spectrum analyzer. In previous experiments a square-law detector is used to measure transmitted wave, however, it includes various spurious components generated at the multiplier. In this system the transmitting power at the notch frequency can be evaluated correctly.

Figure 2 shows the frequency spectra of the sub-harmonic mixer output with no filter and with single and double-layer filter. The incident frequency is adjusted at 154 GHz. It is noted that good rejection is obtained at the notch frequency with double-layer filter. In Fig. 3 is shown an example of frequency dependence. It has 25-30 dB rejection at the designed value, 154 GHz with single-layer filter. It is seen that the rejection becomes double with double-layer filter, which satisfies the required rejection value. We plan to use this notch filter in the FY2012 experimental campaign of LHD

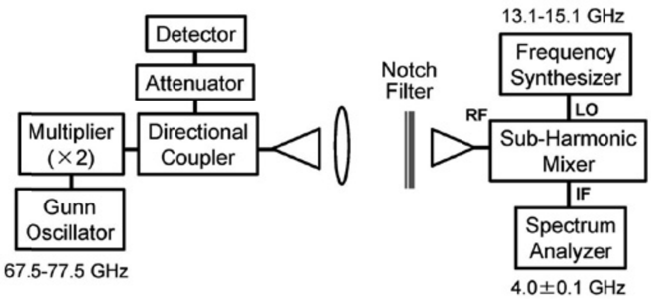

Fig. 1. Schematic of the FSS notch filter testing setup.

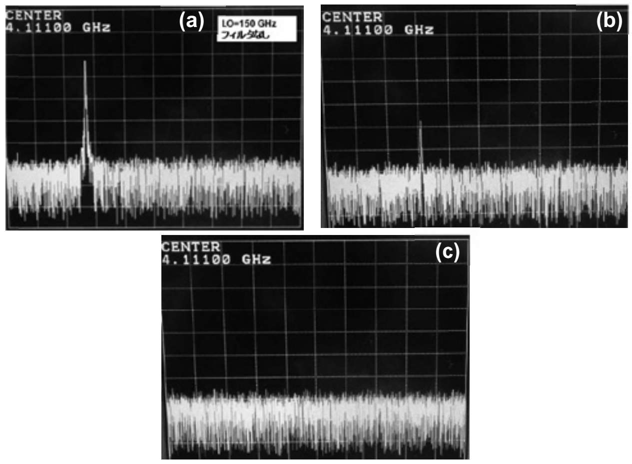

Fig. 2. Measured spectra of sub-harmonic mixer output with (a) no filter, (b) single-layer filter, (c) double-layer filter. center frequency 4.111 GHz, vertical scale 10 dB/div, horizontal scale 20 MHz/div.

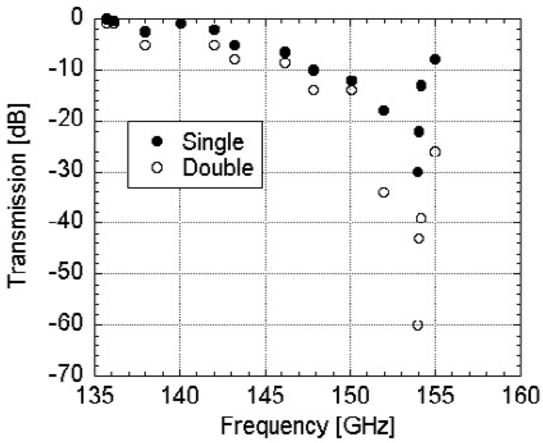

Fig. 3. Transmission property as a function of frequency.

[1] B. Tobias *et al.*, Plasma Fusion Res. **6** (2011) 2106042; Y. Nagayama *et al.*, J. Plasma Fusion Res. **87** (2011) 359.
[2] Z. Shen *et al.*, Plasma Fusion Res. **2** (2007) S1030.
[3] A. Mase *et al.*, J. Instrum. **7** (2012) C01089.