§12. Development of Advanced Microwave Devices for LHD Diagnostic Systems

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Microwave to millimeter-wave diagnostics have been well developed by the advancement of component devices using MIC (microwave integrated circuit) and MMIC (monolithic MIC) technologies. Microwave (active and passive) imaging using these devices is one of the advanced diagnostics to visualize dynamic behavior of plasma fluctuations [1, 2]. The purpose of this research is to develop them mainly for the imaging diagnostics, and to apply to the LHD experiment.

Microwave/millimeter-wave diagnostics in magnetic confinement systems usually require a quasi-optical band-stop filter (notch filter) to prevent spurious electron cyclotron heating power and thus to protect microwave/ millimeter-wave detectors from damage or saturation. The development of notch filters with good performance is one of the high-priority issues in the ITER microwave diagnostics. There are following requirements for the notch filter: i) it must cover the whole area of beam diameter to irradiate the 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.

We have been studying quasioptical microwave filters (frequency selective surface-FSS) in cooperation with Davis Microwave Research Center (DMRC), UCD under the US-Japan Collaboration Program. This year we have designed and fabricated notch filters with notch frequencies of 77 and 154 GHz since gyrotrons with those frequencies are being operated in the LHD experiment. The filters are designed by using an electromagnetic field software, MW Studio (CST Co.) with the period moment method (PMM). The designed shape is the square loop structure, which is fabricated by the etching process.

Due to the small wavelength in the millimeter wave range, the unit cell structures of the notch filters are so small that it is hard to fabricate it precisely. However, in order to obtain the appropriate notch filters, the characterization of S-parameters becomes important, such as, size dependence etc. The characterization of the filters has been performed at POSTECH under the Japan Korea Fusion Collaboration Program as well as at Kyushu University. A network analyzer having the maximum operation frequency 110GHz and 170 GHz is utilized to measure the transmission coefficient (S_{21}). Teflon lenses are applied to the transmitter and the receiver horns to focus the incident beam. The results of S_{21} versus frequency is shown in Fig. 1. It is seen that two filters (b_w120_1 and b_w120_2) have almost the same performance. The notch frequency ~77 GHz is in good agreement with the designed value (theoretical calculation). The attenuation at the notch frequency was 55-60 dB in a single filter which is relatively good performance. The attenuation increases 15-20 dB when two sheets of filter are piled up in one. It is confirmed that the stack structure improves the attenuation. The size dependence of S_{21} is shown in Fig. 2. It is seen that the values of notch frequency shows some discrepancy between measured and calculated values, however, the dependence agrees with each other. By using this result we can fabricate desirable filters for the experiment.

In conclusion, the FSS notch filters with notch frequency of 77 GHz and 154 GHz have been designed and fabricated for application to the LHD microwave diagnostic systems. The characterization was performed by using a vector network analyzer. The notch filters of 110 GHz and 170 GHz have also been fabricated for application to the KSTAR imaging system [3].

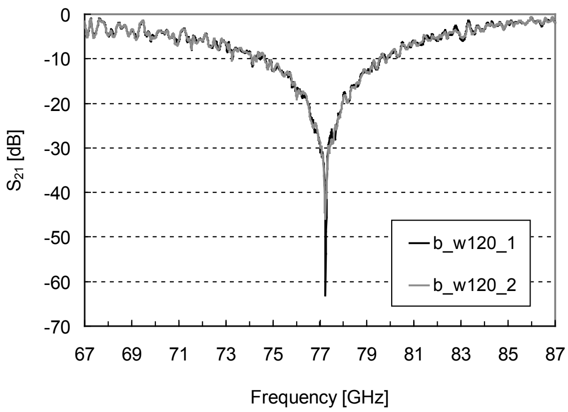

Fig. 1. Transmissivity (S_{21}) vs. frequency.

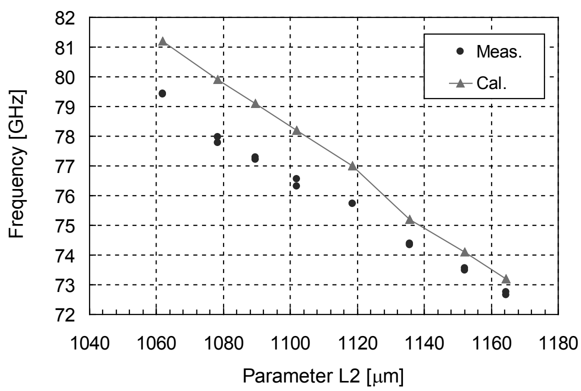

Fig. 2. Notch frequency as a function of pattern size.

[1] Nagayama, Y. *et al.*, Rev. Sci. Instrum. **83** (2012) 10E305

[2] Mase, A. *et al.*, Proc. 2013 URSI-Int. Symp. Electro-magnetic Theory, Hiroshima (2013) 242 (invited).

[3] J. Leem *et al.*, 2014 KSTAR Conference (Feb. 2014).