§2. Evaluation of Transmission Efficiency by Power Measurement Using a Compact Portable Dummy-Load

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We have developed a compact portable dummy-load to measure millimeter wave power at any places along the transmission lines even in LHD vacuum vessel. Requirements for the porposes are (1) portable and compact, (2) closed system without cooling water and electricity, (3) high precision of temperature measurement, (4) thermal insulation from ambient temperature, (5) rapid thermal equilibration and so on.

The dummy-load consists of 250mm × 250mm × 80mm Teflon® tank (thickness is 10mm), a precise RTD(Resistance Temperature Detector) and a stirrer to uniformize the temperature of absorbing liquid shown in Fig. 1. The Teflon tank can be filled with about 2-liter octanol and is thermally insulated from an aluminum frame surrounding the tank. The RTD has the measurable accuracy of 0.01 degree and the temperature data can be transferred through RS232C and recorded every 0.2 sec. The stirrer is driven by a rechargeable battery. The dummuy-load can be set in the measuring positions both vertically and horizontally.

Teflon is adequate for high power millimeter transmission because of its low permittivity and low loss-tangent. It also has low thermal conductivity. We initially used water as a absorbing liquid. Since water has very high permittivity (88 at 0 deg.C) , the reflection from teflon-water layers is about 80% for the right angle injection. Octanol has low permitivity and low absorption coefficient and has linear absorption of 13 dB per cm traversed[1]. And it has the same level of the boiling point as water. So we chose it as a working liquid.

By using the octanol dummy-load, transmitted power was measured at several positions along the transmission line. Figure 2 shows the result of temperature evolutions of octanol. Injected power into the dummy-load was a single shot of 200kW with 10ms pulse width, which was measured by a normal Teflon tubing-load installed at the MOU out. The temperature reached the maximum about 20 seconds after the pulse, then it gradually decreased. We used the maximum temperature rise to estimate a millimeter wave energy absorbed in the octanol and calculated the power. Such values are also indicated in the Fig. 2. The positions of measuring point are as follows. The position of "MOU out" is the output from the matching optics unit near the gyrotron. The position of "Miterbend in LHD room" locates about 100m apart from "MOU out", in which there are 7 miterbends and a polarizer system that consists of 3 mirrors and 2 polarizers. The position of "LHD window" is about 15m apart from "Miterbend in LHD room" and is just above the LHD injection port. Finally the position of "in LHD" corresponds to the focal point of the mirror antenna on the equatorial plane of LHD. The evaluated transmission efficiency between "MOU out " and "LHD window" is agreed with the value obtained another measuring method within the error of 6%. Big difference was observed between the measured and expected values for the efficiency of "in LHD". After the LHD window, there are only four mirrors and spill-over loss was estimated as 2-4%. The reason is unknown for the present. Possible reasons are an error in measurement method, low mode purity in the waveguide, unexpected absorption on the mirror and so on. The load still needs some improvements, such as stirring working liquid, rapid time response of RTD, reducing reflection from the Teflon surface, thermal insulation from ambient temperature. Those issues are under consideration.

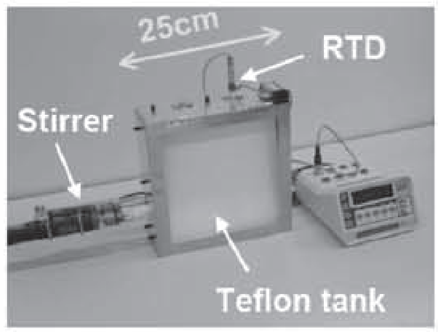

Fig. 1: Teflon® dummy load with RTD and stirrer

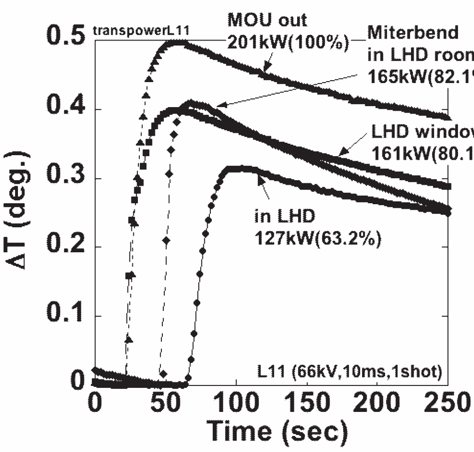

Fig. 2: Time evolution of the temperature of octanol in the dummy-load, which is measured at several positions

References
1) H. Stickle, Int J. Electronics 64, 63 (1988).