§9. Transmission Characteristics of the Sliding Waveguide

K. Ohkubo, S. Kubo, H. Idei, T. Shimozuma
M. Sato and Y. Takita

It is necessary to use the waveguide component for adjusting length of the corrugated (C-) waveguide in the long-line transmission system. The tilting of waveguide with a diameter of 88.9 mm such as 0.1deg makes the loss of 1% in the frequency of 168GHz. Also, it is difficult to fabricate the C-waveguide with bellows-type. We design the short sliding (S-) waveguide with smooth wall is connected to the corrugated waveguides with the inner diameter $2a$ for this purpose as shown in Fig.1. In the component, the inner diameter $2b$ of the S-waveguide is equal to the outer diameter of the fixed C-waveguide.

By normal mode expansion method, an HE_{11} mode in the C-waveguide launcher radiated into the S-waveguide expresses the superposition of the normal TE and TM in the S-waveguide. With the aid of an orthnormal relation between TE and TM modes, the coupling coefficient A_j is calculated from

$$A_j = \iint_S (\boldsymbol{E}_j \times \boldsymbol{H}^*)^* \cdot d\boldsymbol{S}, \qquad (1)$$

where, $\boldsymbol{H}$ is the EM field of the HE_{11} mode at the end of the C-waveguide launcher, and $\boldsymbol{E}_j$ is TE and TM modes, and $\boldsymbol{S}$ is the whole plane of a cross-section.

By using the coupling A_j and wavelength of each modes, two dimensional field patterns at any axial position z in the S-waveguide can be calculated with the superposition of EM-field data in each mode.

Finally, we obtain the power flow P_{WG} into the C-waveguide launcher at the end of the S-waveguide by integration of $\boldsymbol{E} \times \boldsymbol{H}^*$ with in the area of the C-waveguide receiver. In the calculation, only the forward wave is considered and this approximation is valid for small reflection at the junction plane.

The power content $|A_{\mathrm{HE11}}|^2$ mode in the C-waveguide receiver is also calculated easily by the normal mode expansion.

In Fig. 1 P_{WG} and $|A_{\mathrm{HE11}}|^2$ are plotted as function of axial distance z(cm) for the wave frequency of f=84 and 168 GHz. Here, $2a$ and $2b$ are 88.9 mm and 110 mm, respectively.

The loss for 84 GHz is larger than that of 168 GHz and the typical $|A_{\mathrm{HE11}}|^2$ for 84 and 168 GHz at z= 10cm 1.2% and 0.5%, respectively. The value of P_{WG} is nearly equal to $|A_{\mathrm{HE11}}|^2$. It shows that higher-modes can be neglected in this length. To reduce loss to around 0.1%, z should be several cm.

We also calculate $|A_{\mathrm{HE11}}|^2$ in the waveguide gap without the S-waveguide by using 2 dimensional FFT-analysis and the analytic formula $1.7(z\lambda/2a^2)^{3/2}$ (db). In the region of gap, TEM modes (mainly TEM_{00} Gaussain beam) propagate and coupled to hybrid modes in the C-waveguide receiver. The results from $|A_{\mathrm{HE11}}|^2$ and P_{WG} in the waveguide gap are almost equal to that of sliding waveguide system in the range of z=50 cm. Near the opening of oversized waveguide receiver, the wave propagates as if the receiver has no metallic wall of the S-waveguide and then propagates as waveguide modes. The real sliding waveguide for LHD-ECH transmission is coated by MoS_2 to move smoothly and sealed with the O-ring. The components in the transmission lines is well operated in high power level.

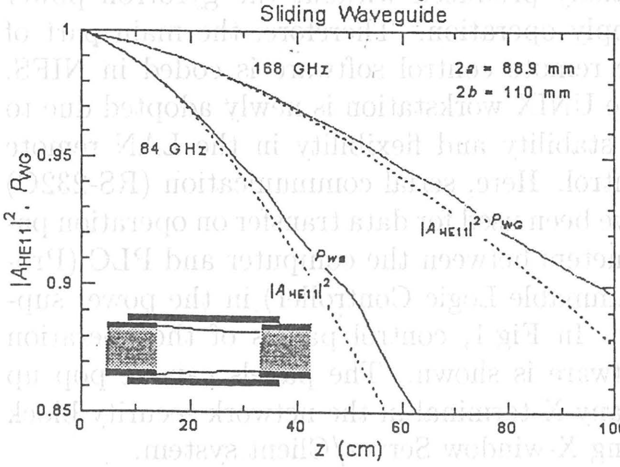

Fig. 1. $|A_{\mathrm{HE11}}|^2$ and P_{WG} for 84 and 168 GHz are plotted as a function of the waveguide length with smooth wall.