§10. Electromagnetic Analysis of the Sliding Waveguide by Mode Matching Method

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To adjust length of the corrugated waveguide in the long line transmission system, we fabricate the short sliding waveguide with smooth wall connected to the corrugated waveguides with the inner diameter $2a = 88.9$ mm. Here, the inner diameter $2b = 110$ mm of the sliding waveguide is equal to the outer diameter of the corrugated waveguide.

By using the electromagnetic analysis on the mode matching method, we take reflection from the discontinuous junction plane into consideration and calculate the complex amplitude of EM-wave in transmission and reflection modes. Equations satisfying the boundary condition at the junction plane are given by

$$\boldsymbol{e}_0^+ + \sum_n^{\infty} A_n \boldsymbol{e}_n^- = \sum_m^{\infty} B_m \boldsymbol{E}_n^+ \qquad (1)$$

$$\boldsymbol{h}_0^+ + \sum_n^{\infty} A_n \boldsymbol{h}_n^- = \sum_m^{\infty} B_m \boldsymbol{H}_m^+ + 2\boldsymbol{h}_0^+ H(a) \qquad (2)$$

where, the relation $\boldsymbol{e}_n^+ = \boldsymbol{e}_n^-$ and $\boldsymbol{h}_n^+ = -\boldsymbol{h}_n^-$ are satisfied. To determine the coefficients A_n and B_m, the least square method is adopted:

$$\Gamma_N = \frac{\int_S |\boldsymbol{e}_0^+ + \sum_n^N A_n \boldsymbol{e}_n^- - \sum_m^N B_m \boldsymbol{E}_n^+|^2 dS}{\int_S |\boldsymbol{e}_0^+|^2 dS} + \frac{\int_S |\boldsymbol{h}_0^+ + \sum_n^N A_n \boldsymbol{h}_n^- - \sum_m^N B_m \boldsymbol{H}_m^+ - 2\boldsymbol{h}_0^+ H(a)|^2 dS}{\int_S |\boldsymbol{h}_0^+|^2 dS}$$

where, m, n are mode number, (+, -) is the traveling direction of wave. EM-fields $(\boldsymbol{e}_0^+, \boldsymbol{h}_0^+)$,$(\boldsymbol{e}_n^-, \boldsymbol{h}_n^-)$ are the incident and reflected wave in input waveguide and $(\boldsymbol{E}_m^+, \boldsymbol{H}_m^+)$ transmitted wave to the output waveguide. In Eq. (2) on boundary equations, the term including the Heviside function H is induced field at the ring-shaped metal wall in the junction plane when the wave in the smooth-wall waveguide is injected the corrugated waveguide. If $N = \infty$, Γ_∞ is equal to zero. In finite mode number N,

$$\partial \Gamma_N / \partial A_i = 0, \partial \Gamma_N / \partial B_i = 0 \qquad (3)$$

are satisfied in order to minimize Γ_N. Because A_i and B_i are complex in general, we solve the $4N$ simultaneous linear equations:

$$\Re[Q(i)] = -\sum_j (\Re A_j) T(i,j) + \sum_j (\Re B_j) U(i,j)$$

$$\Im[Q(i)] = -\sum_j (\Im A_j) T(i,j) + \sum_j (\Im B_j) U(i,j)$$

$$\Re[R(i)] = -\sum_j (\Re A_j) V(i,j) + \sum_j (\Re B_j) W(i,j)$$

$$\Im[R(i)] = -\sum_j (\Im A_j) V(i,j) + \sum_j (\Im B_j) W(i,j)$$

where, matrices $Q(i)$, $R(i)$, $T(i,j)$, $U(i,j)$, $V(i,j)$ and $W(i,j)$ are constants. At the input-junction from the corrugated waveguide to smooth waveguide, the same analysis method is used except that the term with Heviside function is eliminated.

Figure 1 shows the results when HE_{11} mode is injected into the sliding waveguide for 84 GHz. Here, 10 reflected modes and 10 transmitted modes are used and 40 simultaneous linear equations are solved. The reflection of 0.01% at the output junction-plane with sliding length $L = 2$cm is very small.

The sliding waveguide on ECH transmission system in the LHD is sealed with the silicon O-ring and coated by MoS_2 on the sliding surface. The components is well-operated in high-power transmission.

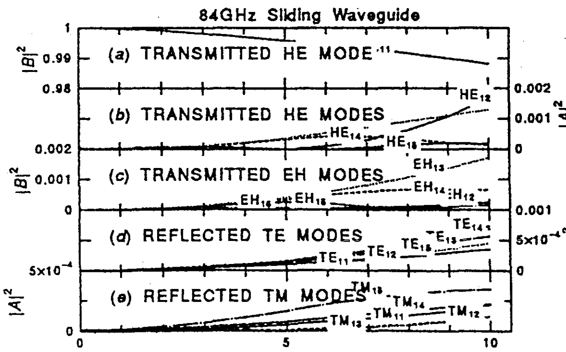

Figure 1: $|B|^2$ of transmitted modes and $|A|^2$ of reflected modes as a function of sliding distance L.