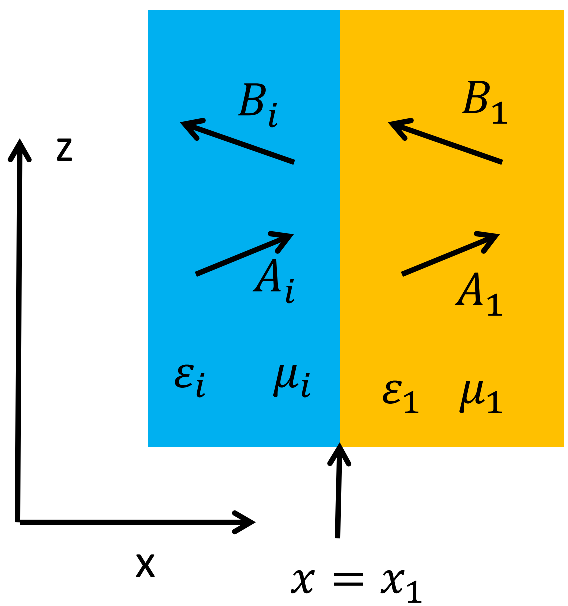
Boundary Condition: TE



Incidence layer:

$$E_{iy} = e^{j(\omega t-\beta z)}\left\{A_i e^{-jk_{ix}(x-x_1)} + B_i e^{jk_{ix}(x-x_1)}\right\}$$

$$H_{iz} = \frac{1}{\omega\mu_i} e^{j(\omega t-\beta z)}\left\{k_{ix}A_i e^{-jk_{ix}(x-x_1)} - k_{ix}B_i e^{jk_{ix}(x-x_1)}\right\}$$

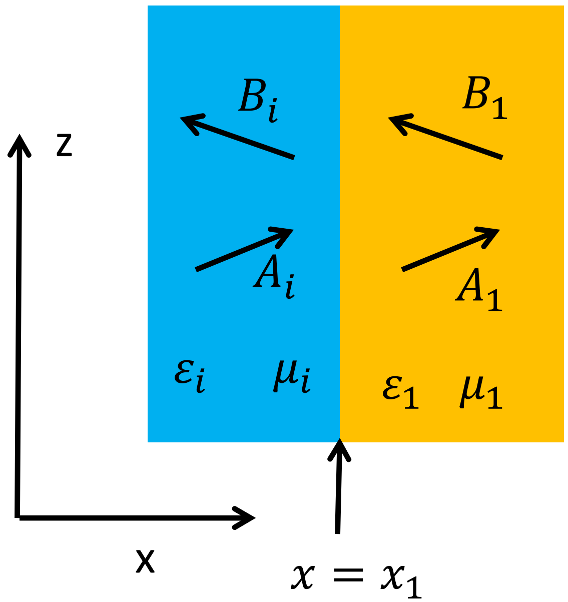
1st layer:

$$E_{1y} = e^{j(\omega t-\beta z)}\left\{A_1 e^{-jk_{1x}(x-x_1)} + B_1 e^{jk_{1x}(x-x_1)}\right\}$$

$$H_{1z} = \frac{1}{\omega\mu_1} e^{j(\omega t-\beta z)}\left\{k_{1x}A_1 e^{-jk_{1x}(x-x_1)} - k_{1x}B_1 e^{jk_{1x}(x-x_1)}\right\}$$

Assign as HW, calculate two H field components and check boundary conditions.

Boundary Condition: TE



$x = x_1$ Incidence layer:

$$E_{iy} = e^{j(\omega t - \beta z)}\{A_i + B_i\}$$

$$H_{iz} = \frac{1}{\omega\mu_i} e^{j(\omega t - \beta z)}\{k_{ix}A_i - k_{ix}B_i\}$$

1st layer:

$$E_{1y} = e^{j(\omega t - \beta z)}\{A_1 + B_1\}$$

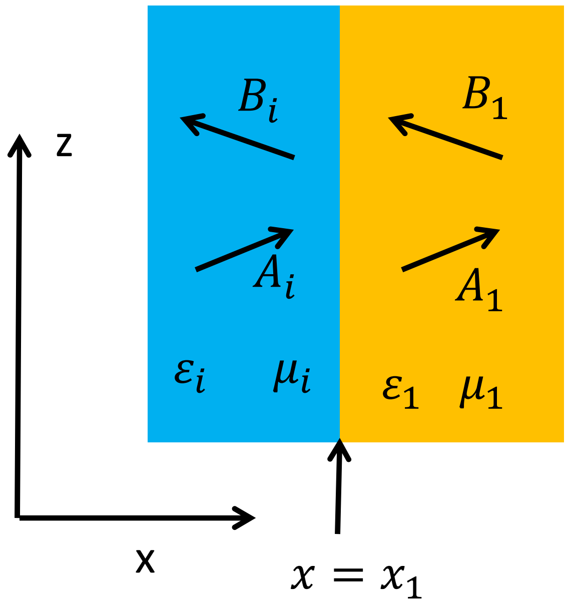
$$H_{1z} = \frac{1}{\omega\mu_1} e^{j(\omega t - \beta z)}\{k_{1x}A_1 - k_{1x}B_1\}$$

$$A_i + B_i = A_1 + B_1$$

$$\frac{1}{\mu_i}\{k_{ix}A_i - k_{ix}B_i\} = \frac{1}{\mu_1}\{k_{1x}A_1 - k_{1x}B_1\}$$

$$\begin{bmatrix} 1 & 1 \\ \dfrac{k_{ix}}{\mu_i} & -\dfrac{k_{ix}}{\mu_i} \end{bmatrix} \begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ \dfrac{k_{1x}}{\mu_1} & -\dfrac{k_{1x}}{\mu_1} \end{bmatrix} \begin{bmatrix} A_1 \\ B_1 \end{bmatrix}$$

Boundary Condition: TE

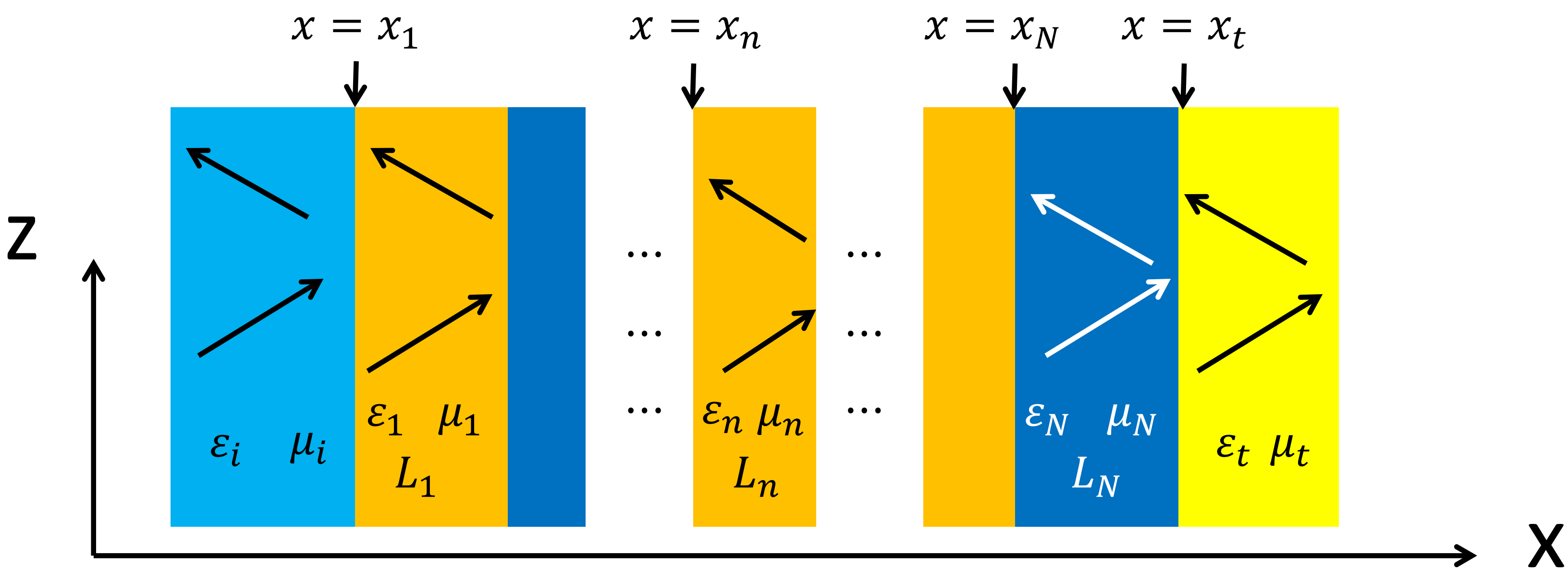


$$\begin{bmatrix} 1 & 1 \\ \dfrac{k_{ix}}{\mu_i} & -\dfrac{k_{ix}}{\mu_i} \end{bmatrix} \begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ \dfrac{k_{1x}}{\mu_1} & -\dfrac{k_{1x}}{\mu_1} \end{bmatrix} \begin{bmatrix} A_1 \\ B_1 \end{bmatrix}$$

$$D_i^{TE} \begin{bmatrix} A_i \\ B_i \end{bmatrix} = D_1^{TE} \begin{bmatrix} A_1 \\ B_1 \end{bmatrix}$$

$$D_n^{TE} = \begin{bmatrix} 1 & 1 \\ \dfrac{k_{nx}}{\mu_n} & -\dfrac{k_{nx}}{\mu_n} \end{bmatrix}$$

TE Transfer Matrix



$$\begin{bmatrix} A_t \\ B_t \end{bmatrix} = [(D_t^{TE})^{-1} D_N^{TE} P_N^{TE}] T_{N-1}^{TE} \cdots T_n^{TE} \cdots T_2^{TE} T_1^{TE} [(D_1^{TE})^{-1} D_i^{TE}] \begin{bmatrix} A_i \\ B_i \end{bmatrix}$$

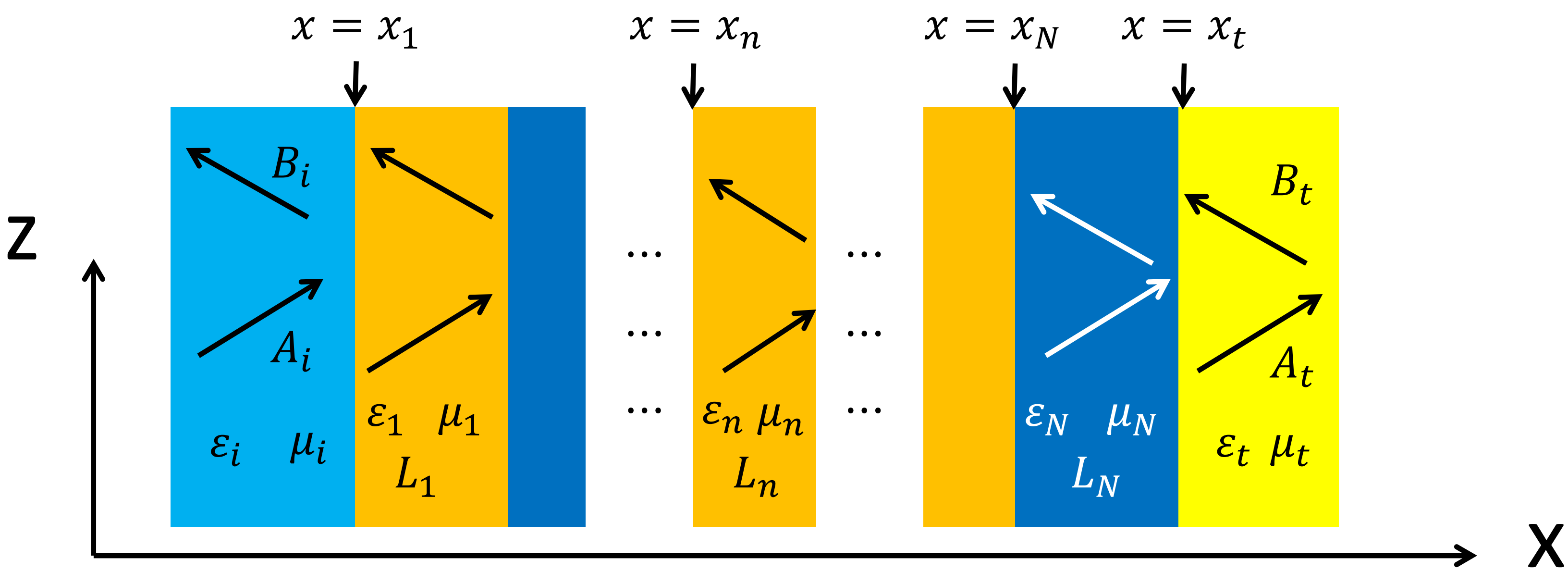
$$\begin{bmatrix} A_t \\ B_t \end{bmatrix} = T_{TE} \begin{bmatrix} A_i \\ B_i \end{bmatrix}$$

$$T_n = [D_{n+1}^{TE}]^{-1} D_n^{TE} P_n^{TE}$$

$$T_{TE} = [(D_t^{TE})^{-1} D_N^{TE} P_N^{TE}] T_{N-1}^{TE} \cdots T_n^{TE} \cdots T_2^{TE} T_1^{TE} [(D_1^{TE})^{-1} D_i^{TE}]$$

Assign as HW: determine the transfer matrix between the Nth and the transmission layer.

Reflection and Transmission: TE



$$\begin{bmatrix} A_t \\ B_t \end{bmatrix} = T_{TE} \begin{bmatrix} A_i \\ B_i \end{bmatrix}$$

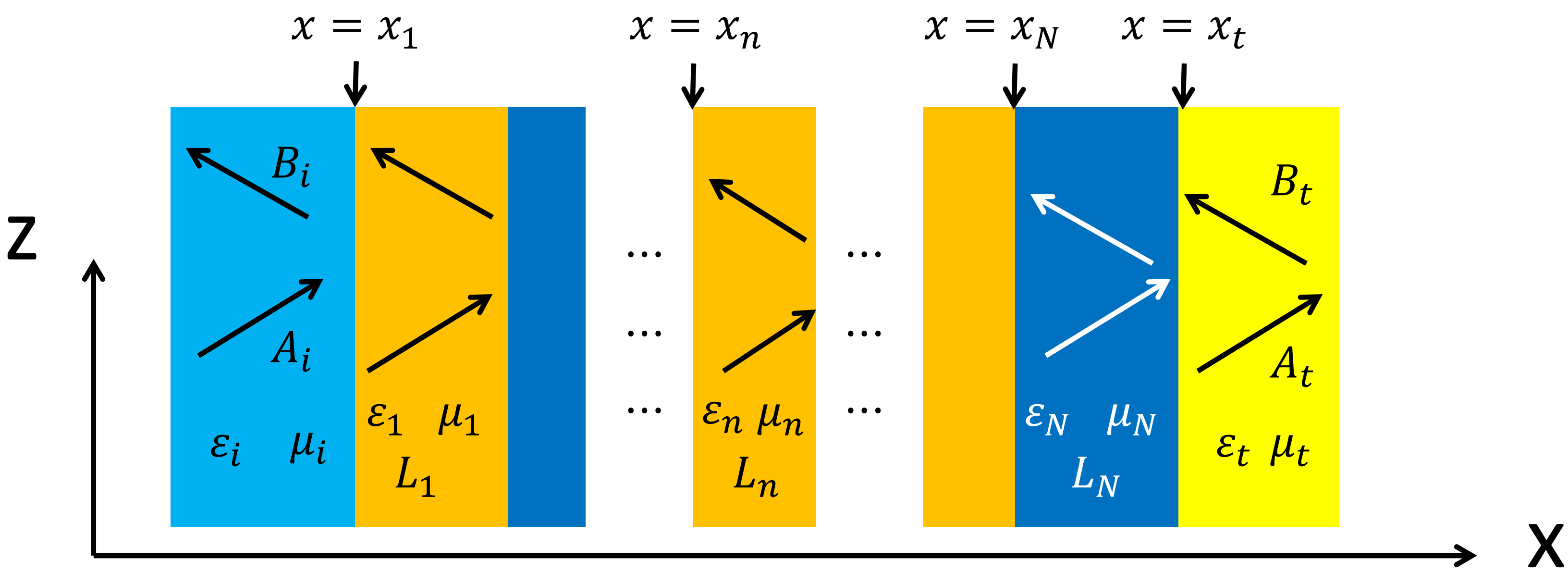
Boundary Condition:
Only outgoing uniform EM wave exist in the transmission layer

$$k_{nx} = \sqrt{\omega^2 \varepsilon_t \mu_t - \beta^2} \qquad \beta < \omega\sqrt{\varepsilon_t \mu_t}$$

$$\begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} (T_{TE}^{-1})_{11} & (T_{TE}^{-1})_{12} \\ (T_{TE}^{-1})_{21} & (T_{TE}^{-1})_{22} \end{bmatrix} \begin{bmatrix} A_t \\ B_t \end{bmatrix}$$

$$\begin{bmatrix} A_t \\ B_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad \begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} (T_{TE}^{-1})_{11} \\ (T_{TE}^{-1})_{21} \end{bmatrix}$$

Reflection: TE



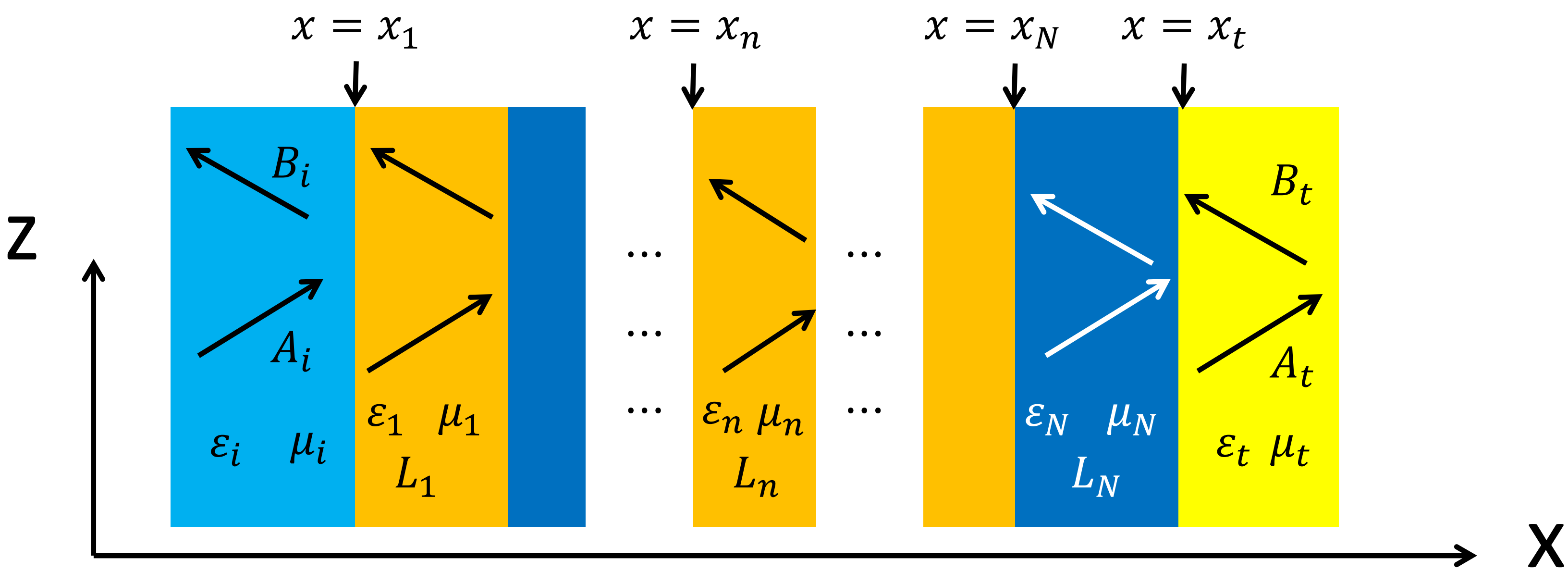
$$\beta < \omega\sqrt{\varepsilon_t \mu_t} \qquad \begin{bmatrix} A_t \\ B_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} (T_{TE}^{-1})_{11} \\ (T_{TE}^{-1})_{21} \end{bmatrix}$$

S_{rx}: Poynting vector associated with the reflected wave.
S_{tx}: Poynting vector associated with the transmitted wave.

$$R = \frac{S_{rx}}{S_{ix}} = \left|\frac{B_i}{A_i}\right|^2 = \left|\frac{(T_{TE}^{-1})_{21}}{(T_{TE}^{-1})_{11}}\right|^2$$

Reflection coefficient R represents the fraction of EM wave reflected back by the planar structure.

Transmission: TE



$$\beta < \omega\sqrt{\varepsilon_t \mu_t}$$

$$E_{iy} = e^{j(\omega t - \beta z)}\{A_i e^{-jk_{ix}(x-x_1)} + B_i e^{jk_{ix}(x-x_1)}\}$$

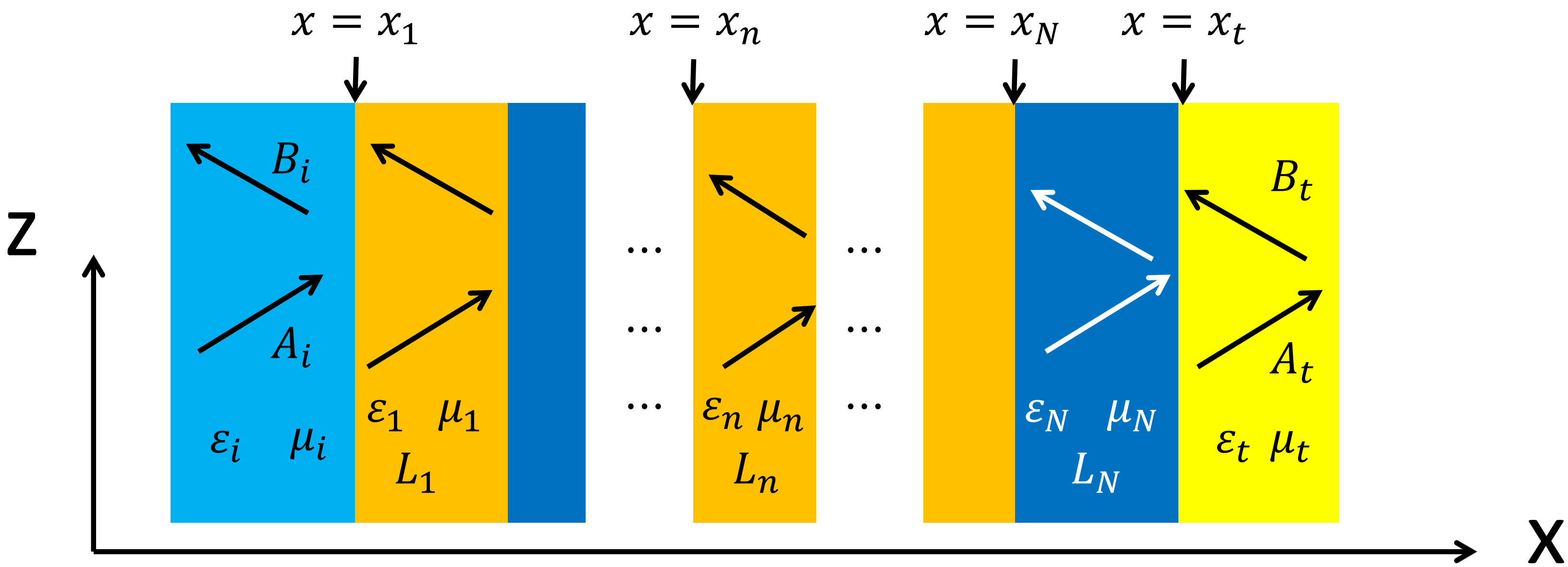
$$E_{ty} = e^{j(\omega t - \beta z)}\{A_t e^{-jk_{tx}(x-x_t)} + B_t e^{jk_{tx}(x-x_t)}\}$$

$$\vec{E}(\vec{r}, t) = E_0 e^{j\omega t} e^{-jk_0 z}\,\vec{e}_x$$

$$\vec{S}(\vec{r}, t) = \frac{1}{2}\frac{k_0}{\omega\mu}|E_0|^2\,\vec{e}_z$$

$$S_{ix} = \frac{k_{ix}}{2\omega\mu_i}|\mathrm{A_i}|^2 \qquad S_{tx} = \frac{k_{tx}}{2\omega\mu_t}|A_t|^2$$

Transmission: TE



$$\beta < \omega\sqrt{\varepsilon_t \mu_t}$$

$$\begin{bmatrix} A_t \\ B_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} (T_{TE}^{-1})_{11} \\ (T_{TE}^{-1})_{21} \end{bmatrix}$$

$$T = \frac{S_{tx}}{S_{ix}} = \frac{\frac{k_{tx}}{2\omega\mu_t}|A_t|^2}{\frac{k_{ix}}{2\omega\mu_i}|\mathrm{A_i}|^2} = \frac{\mu_i k_{tx}}{\mu_t k_{ix}} \frac{1}{|(T_{TE}^{-1})_{11}|^2}$$

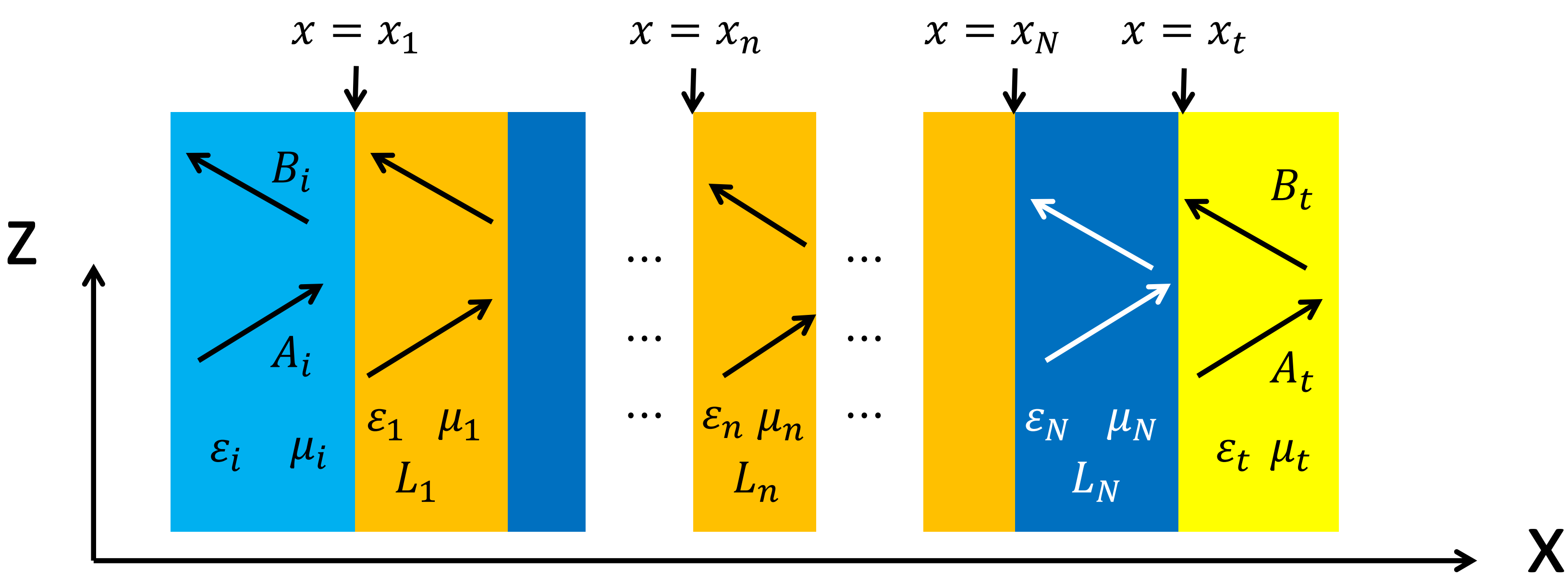
Reflection and Transmission: TE

- EM fields take the form of uniform plane wave in the transmission layer: $\beta < \omega\sqrt{\varepsilon_t \mu_t}$
- Calculate the transmission matrix of the entire layered planar structure: $\begin{bmatrix} A_t \\ B_t \end{bmatrix} = T_{TE} \begin{bmatrix} A_i \\ B_i \end{bmatrix}$
- Calculate reflection and transmission coefficient: $\begin{bmatrix} A_t \\ B_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ $\begin{bmatrix} A_i \\ B_i \end{bmatrix} = \begin{bmatrix} (T_{TE}^{-1})_{11} \\ (T_{TE}^{-1})_{21} \end{bmatrix}$
- Calculate the (amplitude and power) reflection and transmission coefficients:

$$r = \frac{B_i}{A_i} = \frac{(T_{TE}^{-1})_{21}}{(T_{TE}^{-1})_{11}} \qquad R = \frac{S_{rx}}{S_{ix}} = \left| \frac{(T_{TE}^{-1})_{21}}{(T_{TE}^{-1})_{11}} \right|^2$$

$$t = \frac{A_t}{A_i} = \frac{1}{(T_{TE}^{-1})_{11}} \qquad T = \frac{S_{tx}}{S_{ix}} = \frac{\mu_i k_{tx}}{\mu_t k_{ix}} \frac{1}{|(T_{TE}^{-1})_{11}|^2}$$

TM Solution



Contains Hy, Ex, and Ez components. All other components are zero.

$$\vec{H}_n = e^{j(\omega t-\beta z)}\left\{C_n e^{-jk_{nx}(x-x_n)} + D_n e^{jk_{nx}(x-x_n)}\right\}\vec{e}_y$$

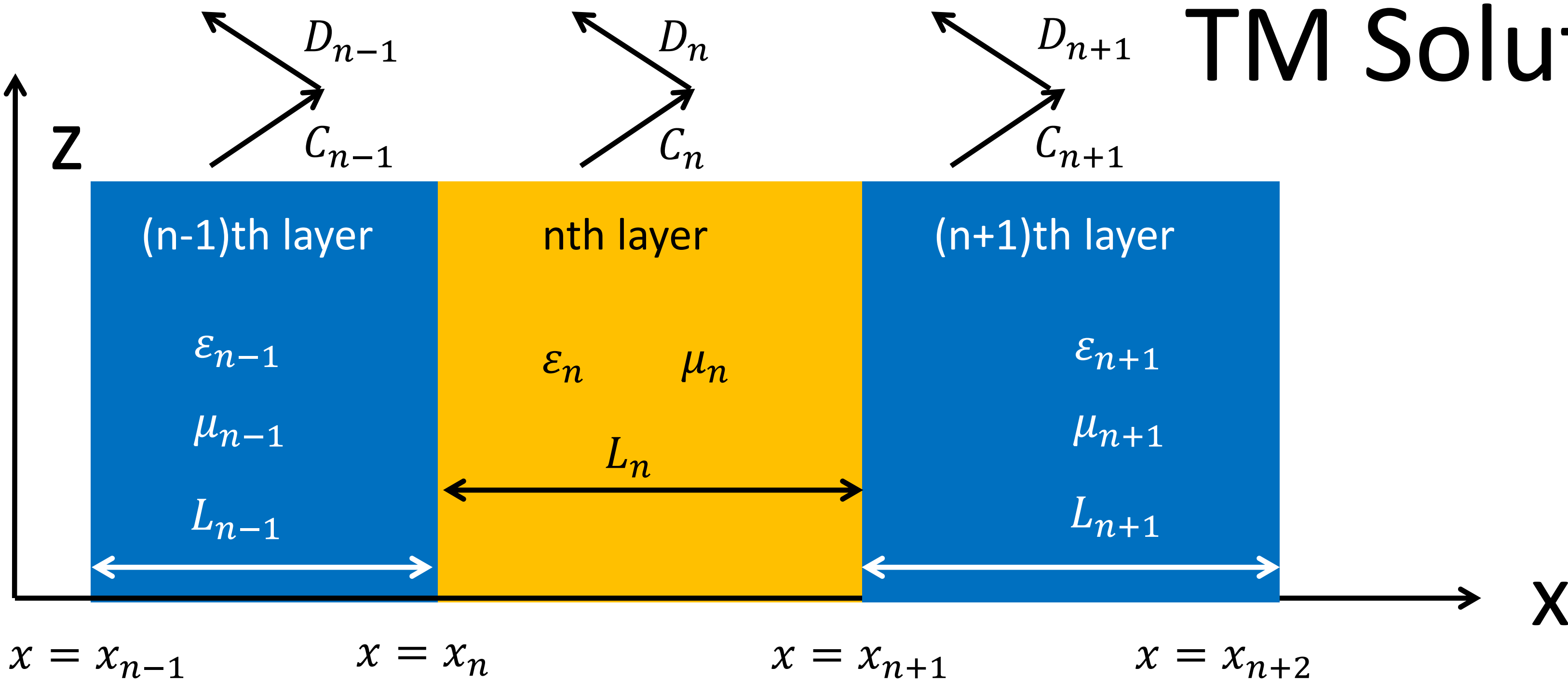
$$\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t}$$

$$\vec{E} = \frac{\nabla \times \vec{H}}{j\varepsilon\omega}$$

$$E_{nx} = \frac{\beta}{\varepsilon_n \omega} e^{j(\omega t-\beta z)}\left\{C_n e^{-jk_{nx}(x-x_n)} + D_n e^{jk_{nx}(x-x_n)}\right\}$$

$$E_{nz} = \frac{1}{j\varepsilon_n \omega} e^{j(\omega t-\beta z)}\left\{-jk_{nx} C_n e^{-jk_{nx}(x-x_n)} + jk_{nx} D_n e^{jk_{nx}(x-x_n)}\right\}$$

TM Solution



$@x = x_{n+1}$

nth layer

$$H_{ny} = e^{j(\omega t - \beta z)}\{C_n e^{-jk_{nx}L_n} + D_n e^{jk_{nx}L_n}\}$$

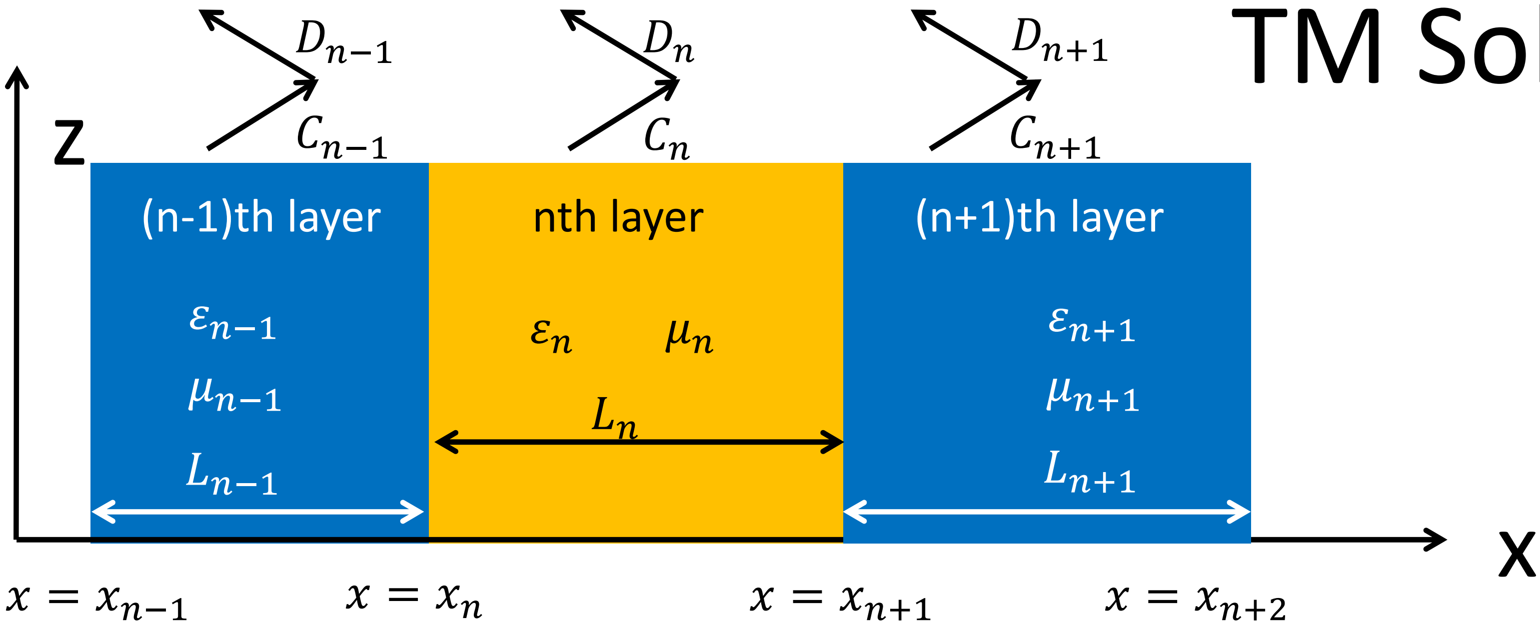
$$E_{nz} = \frac{1}{j\varepsilon_n \omega} e^{j(\omega t - \beta z)}\{-jk_{nx}C_n e^{-jk_{nx}L_n} + jk_{nx}D_n e^{jk_{nx}L_n}\}$$

(n+1)th layer

$$H_{n+1,y} = e^{j(\omega t - \beta z)}\{C_{n+1} + D_{n+1}\}$$

$$E_{n+1,z} = \frac{1}{j\varepsilon_{n+1}\omega} e^{j(\omega t - \beta z)}\{-jk_{n+1,x}C_{n+1} + jk_{n+1,x}D_{n+1}\}$$

TM Solution

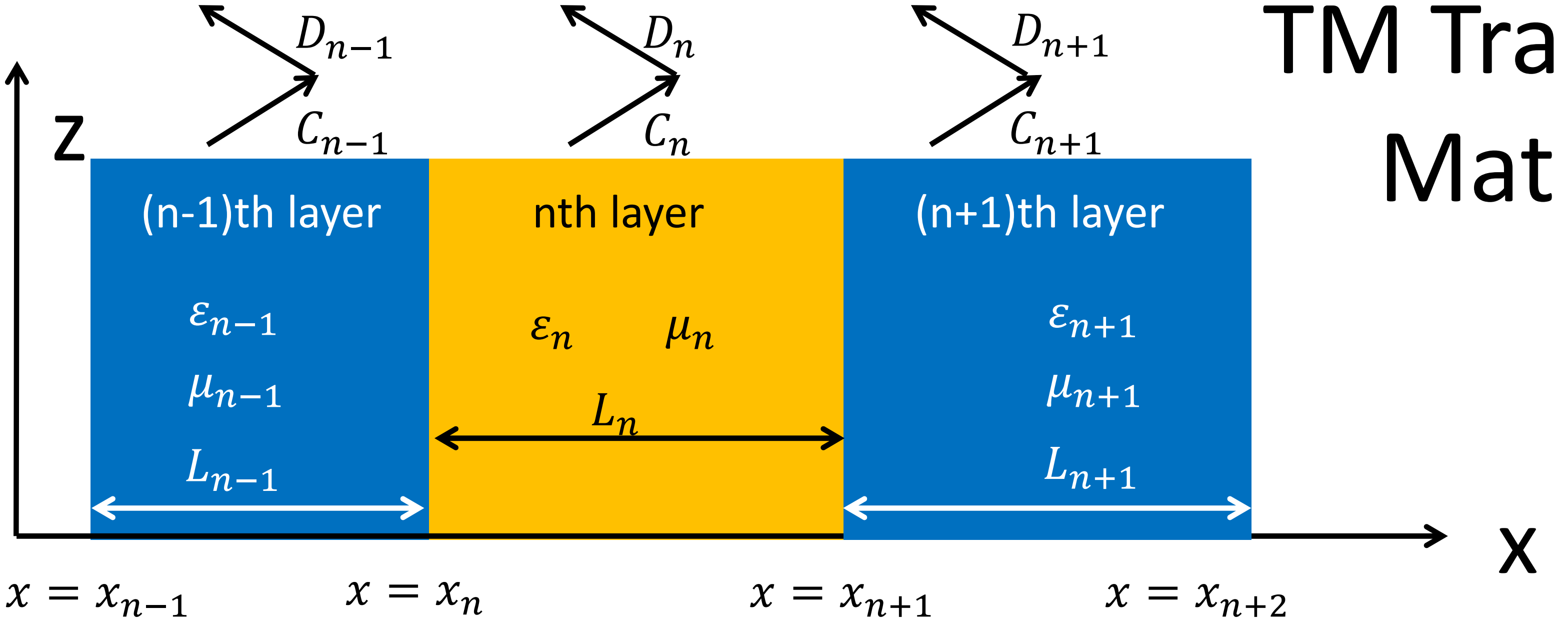


$$C_n e^{-jk_{nx}L_n} + D_n e^{jk_{nx}L_n} = C_{n+1} + D_{n+1}$$

$$\frac{k_{nx}}{\varepsilon_n} C_n e^{-jk_{nx}L_n} - \frac{k_{nx}}{\varepsilon_n} D_n e^{jk_{nx}L_n} = \frac{k_{n+1,x}}{\varepsilon_{n+1}} C_{n+1} - \frac{k_{n+1,x}}{\varepsilon_{n+1}} D_{n+1}$$

$$\begin{bmatrix} 1 & 1 \\ \frac{k_{nx}}{\varepsilon_n} & -\frac{k_{nx}}{\epsilon_n} \end{bmatrix} \begin{bmatrix} e^{-jk_{nx}L_n} & 0 \\ 0 & e^{jk_{nx}L_n} \end{bmatrix} \begin{bmatrix} C_n \\ D_n \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ \frac{k_{n+1,x}}{\varepsilon_{n+1}} & -\frac{k_{n+1,x}}{\varepsilon_{n+1}} \end{bmatrix} \begin{bmatrix} C_{n+1} \\ D_{n+1} \end{bmatrix}$$

TM Transfer Matrix



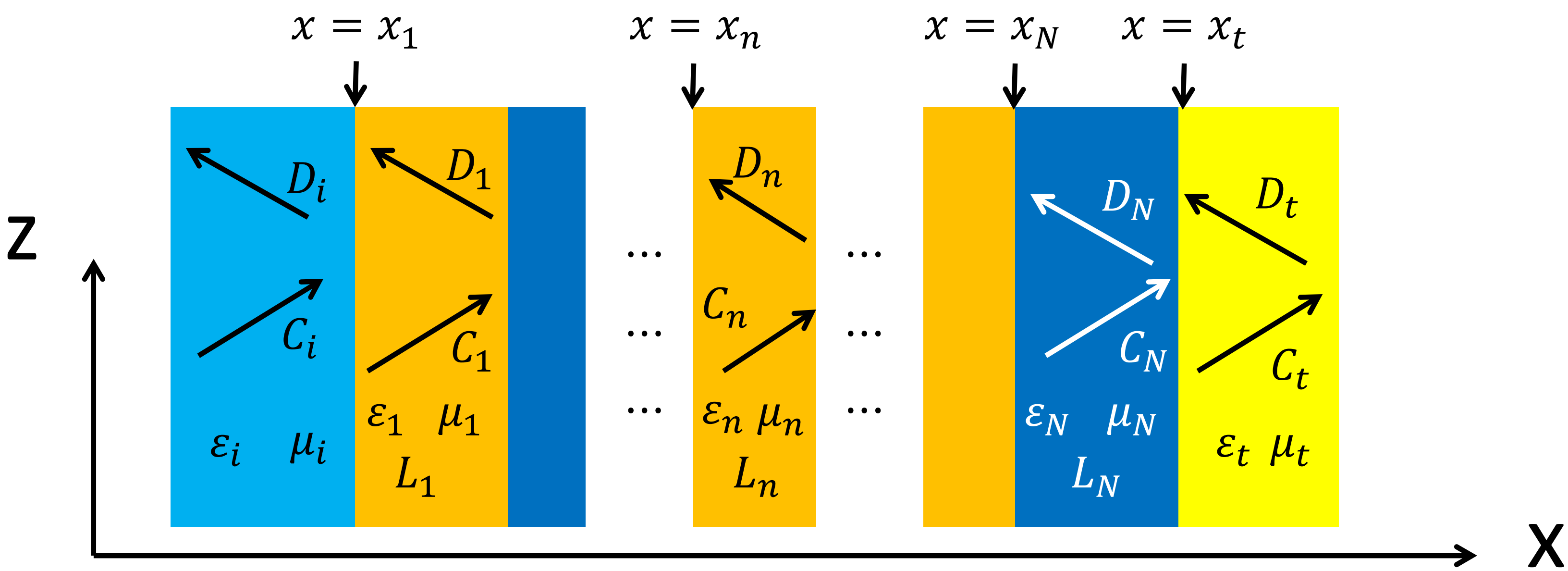
$$D_n^{TM} P_n^{TM} \begin{bmatrix} C_n \\ D_n \end{bmatrix} = D_{n+1}^{TM} \begin{bmatrix} C_{n+1} \\ D_{n+1} \end{bmatrix}$$

$$D_n^{TM} = \begin{bmatrix} 1 & 1 \\ \dfrac{k_{nx}}{\varepsilon_n} & -\dfrac{k_{nx}}{\varepsilon_n} \end{bmatrix}$$

$$P_n^{TM} = \begin{bmatrix} e^{-jk_{nx}L_n} & 0 \\ 0 & e^{jk_{nx}L_n} \end{bmatrix}$$

$$D_{n+1}^{TM} = \begin{bmatrix} 1 & 1 \\ \dfrac{k_{n+1,x}}{\varepsilon_{n+1}} & -\dfrac{k_{n+1,x}}{\varepsilon_{n+1}} \end{bmatrix}$$

TM Transfer Matrix

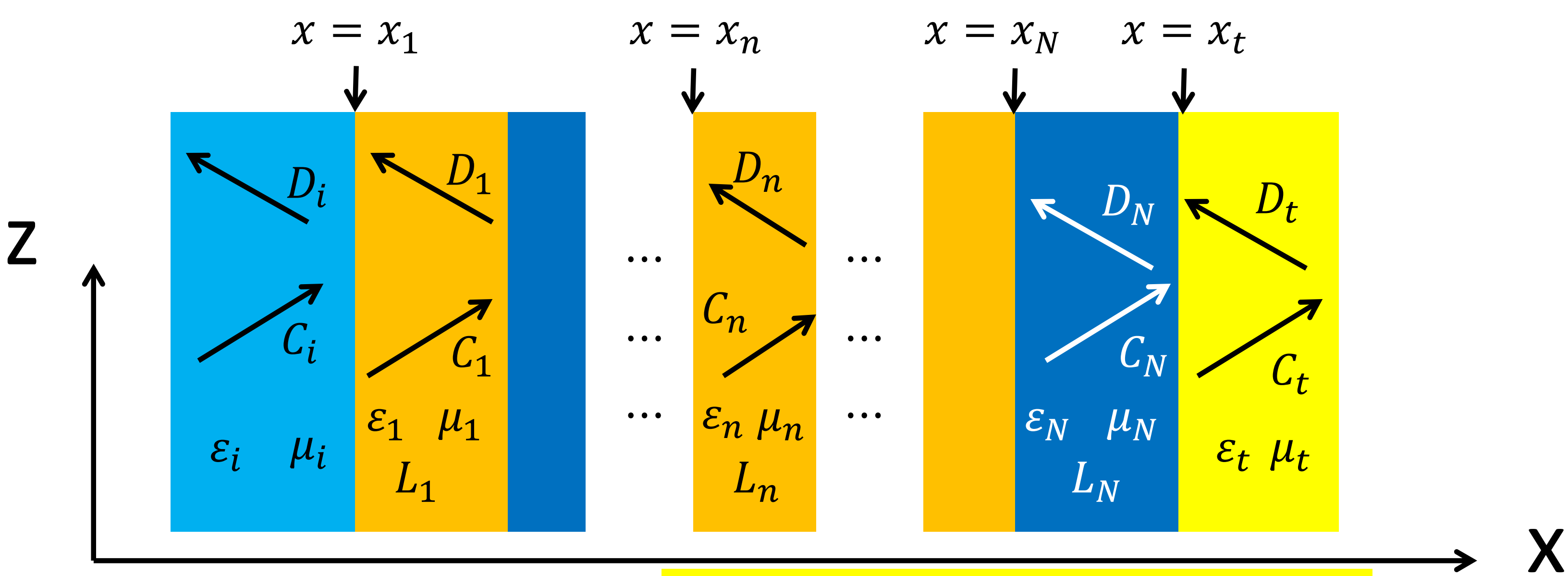


$$\vec{H}_n = e^{j(\omega t - \beta z)}\{C_n e^{-jk_{nx}(x - x_n)} + D_n e^{jk_{nx}(x - x_n)}\}\vec{e}_y$$

$$\begin{bmatrix} C_{n+1} \\ D_{n+1} \end{bmatrix} = T_n^{TM} \begin{bmatrix} C_n \\ D_n \end{bmatrix} \qquad T_n^{TM} = [D_{n+1}^{TM}]^{-1} D_n^{TM} P_n^{TM}$$

$$\begin{bmatrix} C_N \\ D_N \end{bmatrix} = T_{N-1}^{TM} \cdots T_n^{TM} \cdots T_2^{TM} T_1^{TM} \begin{bmatrix} C_1 \\ D_1 \end{bmatrix}$$

Reflection and Transmission: TM



Assign as HW, derive this transfer matrix

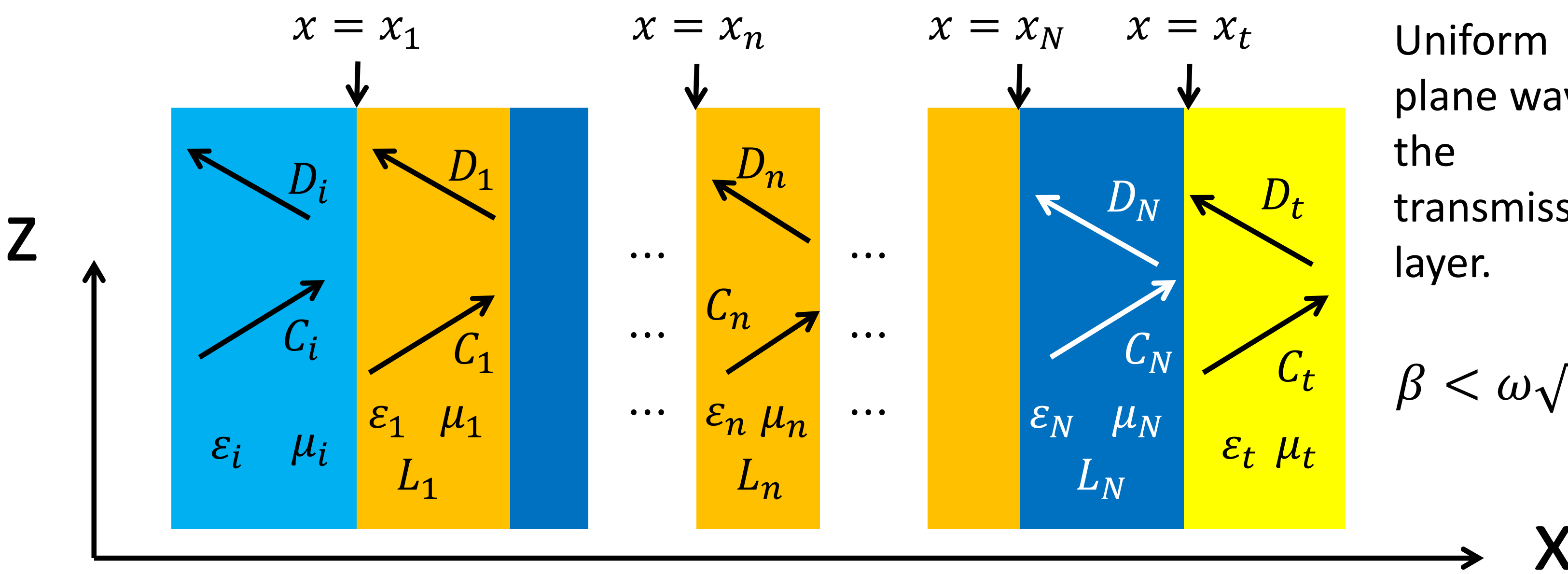
$$\begin{bmatrix} C_t \\ D_t \end{bmatrix} = [(D_t^{TM})^{-1} D_N^{TM} P_N^{TM}] T_{N-1}^{TM} \cdots T_n^{TM} \cdots T_2^{TM} T_1^{TM} \left[(D_1^{TM})^{-1} D_i^{TM}\right] \begin{bmatrix} C_i \\ D_i \end{bmatrix}$$

$$\begin{bmatrix} C_t \\ D_t \end{bmatrix} = T_{TM} \begin{bmatrix} C_i \\ D_i \end{bmatrix}$$

$$T_n^{TM} = [D_{n+1}^{TM}]^{-1} D_n^{TM} P_n^{TM}$$

$$T_{TM} = [(D_t^{TM})^{-1} D_N^{TM} P_N^{TM}] T_{N-1}^{TM} \cdots T_n^{TM} \cdots T_2^{TM} T_1^{TM} \left[(D_1^{TM})^{-1} D_i^{TM}\right]$$

Reflection and Transmission: TM



Uniform plane wave in the transmission layer.

$$\beta < \omega\sqrt{\varepsilon_t \mu_t}$$

$$\vec{H}_n = e^{j(\omega t - \beta z)}\{C_n e^{-jk_{nx}(x-x_n)} + D_n e^{jk_{nx}(x-x_n)}\}\vec{e}_y$$

Uniform Plane Wave $\quad Z = \dfrac{|\vec{E}|}{|\vec{H}|} = \sqrt{\dfrac{\mu}{\varepsilon}}$

$$|\vec{S}| = \frac{1}{2}Re\left[|\vec{E} \times \vec{H}^*|\right] = \frac{1}{2Z}|\vec{E}|^2 = \frac{Z}{2}|\vec{H}|^2$$

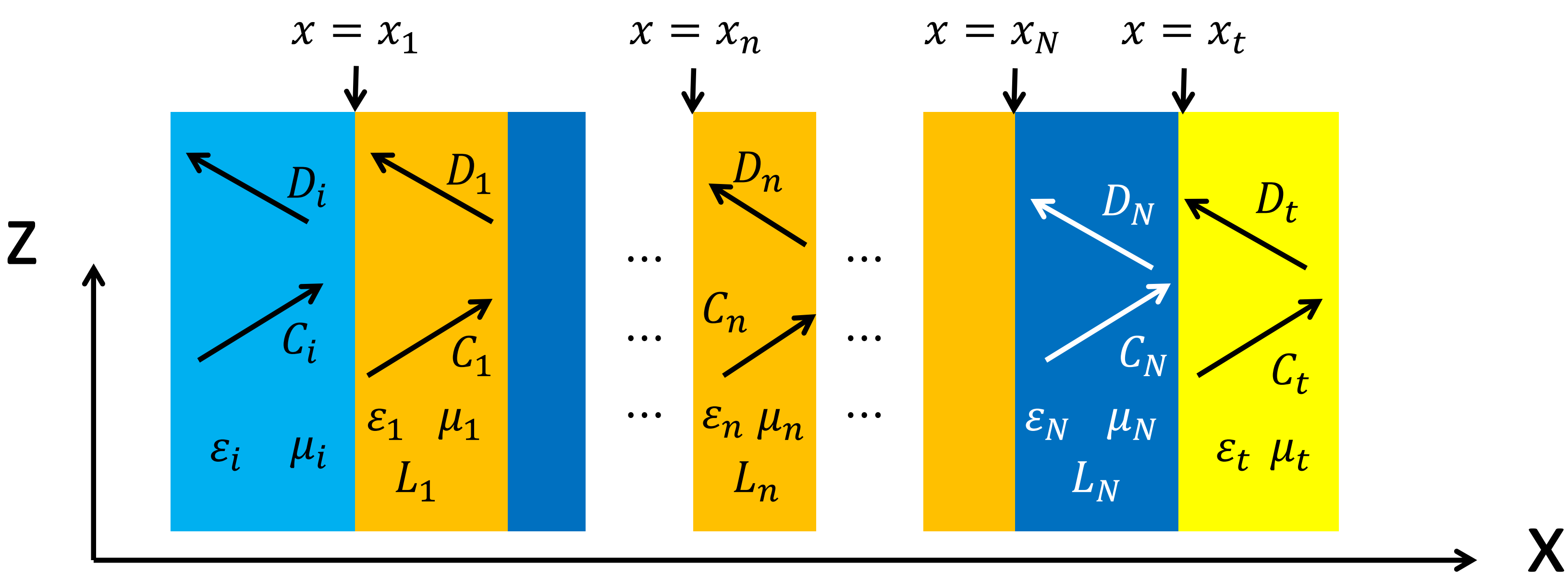
$$|\vec{S}| = \frac{1}{2}\frac{k}{\omega\mu}|\vec{E}|^2 = \frac{1}{2}\frac{k}{\omega\mu}\frac{\mu}{\varepsilon}|\vec{H}|^2 = \frac{1}{2}\frac{k}{\omega\varepsilon}|\vec{H}|^2$$

$$S_{ix} = \frac{1}{2}\frac{k_{ix}}{\omega\varepsilon_i}|C_i|^2$$

$$S_{rx} = \frac{1}{2}\frac{k_{ix}}{\omega\varepsilon_i}|D_i|^2$$

$$S_{tx} = \frac{1}{2}\frac{k_{tx}}{\omega\varepsilon_t}|C_t|^2$$

Reflection and Transmission: TM



Uniform plane wave in the transmission layer.

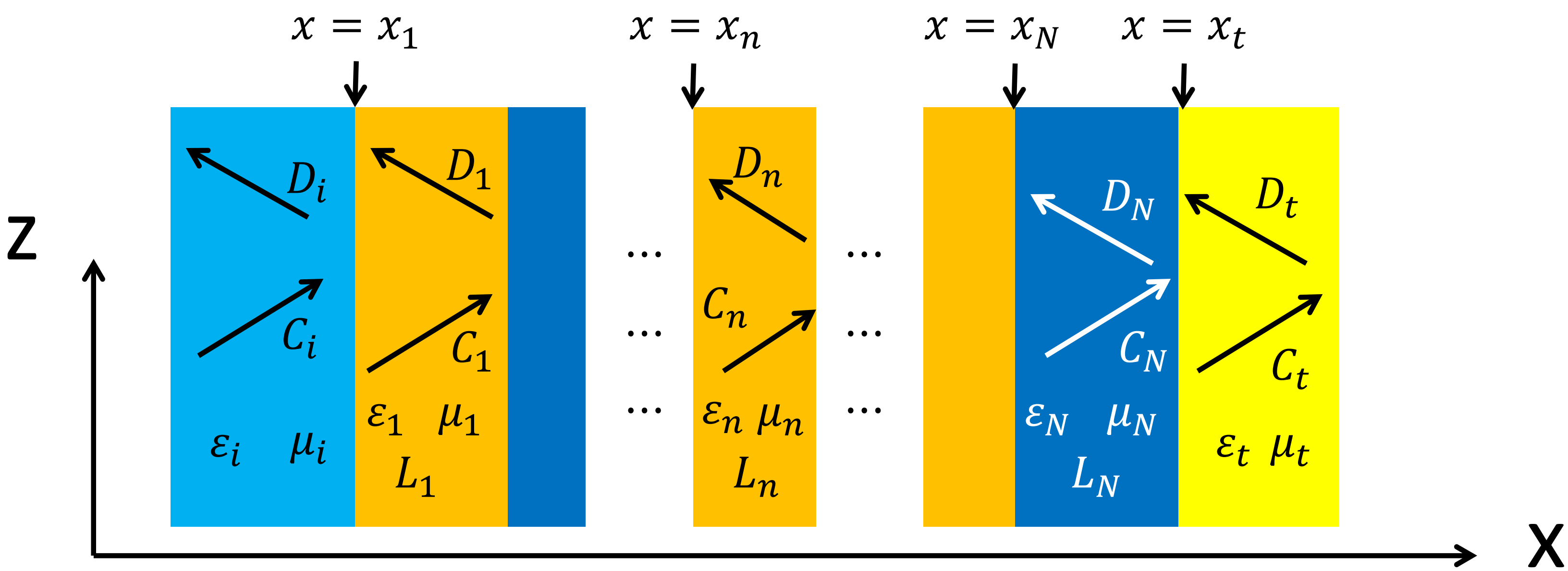
$$\beta < \omega\sqrt{\varepsilon_t\mu_t}$$

$$\begin{bmatrix} C_t \\ D_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} C_i \\ D_i \end{bmatrix} = \begin{bmatrix} (T_{TM}^{-1})_{11} \\ (T_{TM}^{-1})_{21} \end{bmatrix}$$

$$\begin{bmatrix} C_t \\ D_t \end{bmatrix} = T_{TM} \begin{bmatrix} C_i \\ D_i \end{bmatrix}$$

$$R = \frac{S_{rx}}{S_{ix}} = \left|\frac{D_i}{C_i}\right|^2 = \left|\frac{(T_{TM}^{-1})_{21}}{(T_{TM}^{-1})_{11}}\right|^2$$

Reflection and Transmission: TM



$$\beta < \omega\sqrt{\varepsilon_t \mu_t} \qquad \begin{bmatrix} C_t \\ D_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \qquad \begin{bmatrix} C_i \\ D_i \end{bmatrix} = \begin{bmatrix} (T_{TM}^{-1})_{11} \\ (T_{TM}^{-1})_{21} \end{bmatrix}$$

$$T = \frac{S_{tx}}{S_{ix}} = \frac{\frac{1}{2}\frac{k_{tx}}{\omega\varepsilon_t}|C_t|^2}{\frac{1}{2}\frac{k_{ix}}{\omega\varepsilon_i}|C_i|^2} = \frac{\varepsilon_i k_{tx}}{\varepsilon_t k_{ix}}\frac{1}{|(T_{TM}^{-1})_{11}|^2}$$

Reflection and Transmission: TM

- EM fields take the form of uniform plane wave in the transmission layer: $\beta < \omega\sqrt{\varepsilon_t \mu_t}$

- Calculate the transmission matrix of the entire layered planar structure: $\begin{bmatrix} C_t \\ D_t \end{bmatrix} = T_{TM} \begin{bmatrix} C_i \\ D_i \end{bmatrix}$

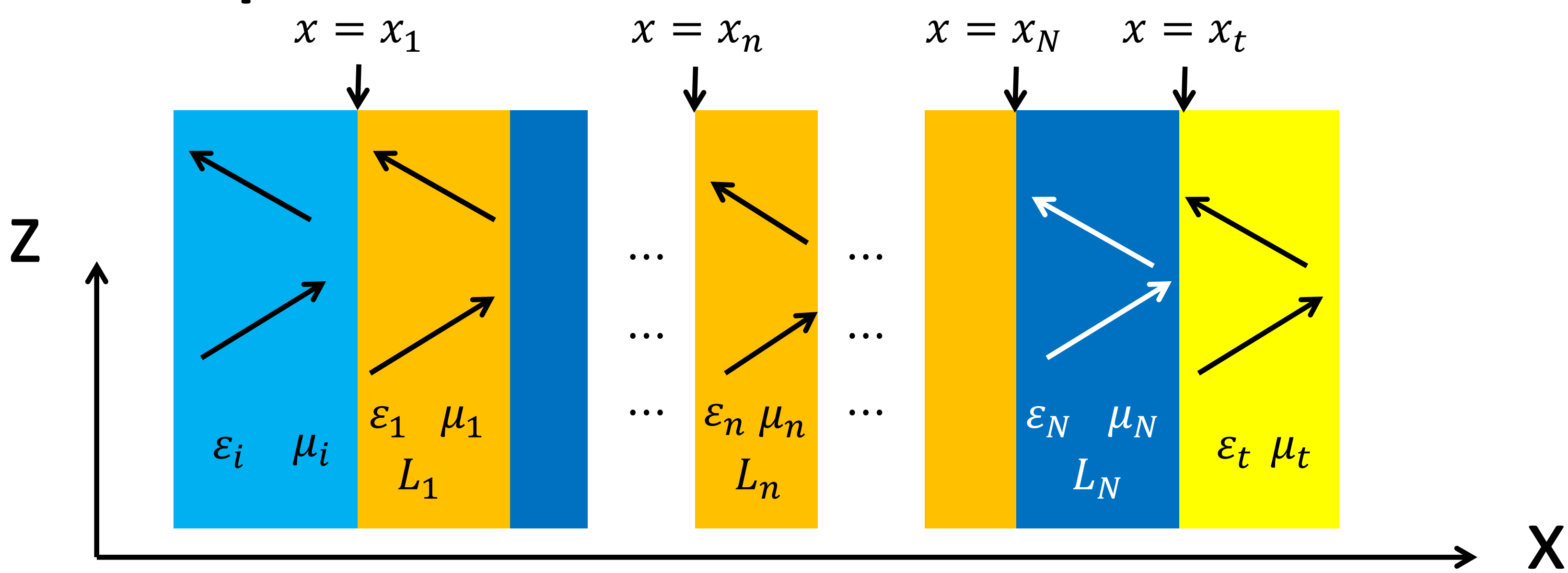
- Calculate reflection and transmission coefficient: $\begin{bmatrix} C_t \\ D_t \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ $\quad \begin{bmatrix} C_i \\ D_i \end{bmatrix} = \begin{bmatrix} (T_{TM}^{-1})_{11} \\ (T_{TM}^{-1})_{21} \end{bmatrix}$

- Calculate the (amplitude and power) reflection and transmission coefficients:

$$r = \frac{D_i}{C_i} = \frac{(T_{TM}^{-1})_{21}}{(T_{TM}^{-1})_{11}} \qquad R = \frac{S_{rx}}{S_{ix}} = \left| \frac{(T_{TM}^{-1})_{21}}{(T_{TM}^{-1})_{11}} \right|^2$$

$$t = \frac{C_t}{C_i} = \frac{1}{(T_{TM}^{-1})_{11}} \qquad T = \frac{S_{tx}}{S_{ix}} = \frac{\varepsilon_i k_{tx}}{\varepsilon_t k_{ix}} \frac{1}{|(T_{TM}^{-1})_{11}|^2}$$

Comparison of TE and TM Cases



TE E_y H_x H_z

$$\vec{E}_n = e^{j(\omega t - \beta z)}\{A_n e^{-jk_{nx}(x-x_n)} + B_n e^{jk_{nx}(x-x_n)}\}\vec{e}_y$$

$$H_{nx} = -\frac{\beta}{\omega \mu_n} e^{j(\omega t - \beta z)}\{A_n e^{-jk_{nx}(x-x_n)} + B_n e^{jk_{nx}(x-x_n)}\}$$

$$H_{nz} = \frac{1}{\omega \mu_n} e^{j(\omega t - \beta z)}\{k_{nx} A_n e^{-jk_{nx}(x-x_n)} - k_{nx} B_n e^{jk_{nx}(x-x_n)}\}$$

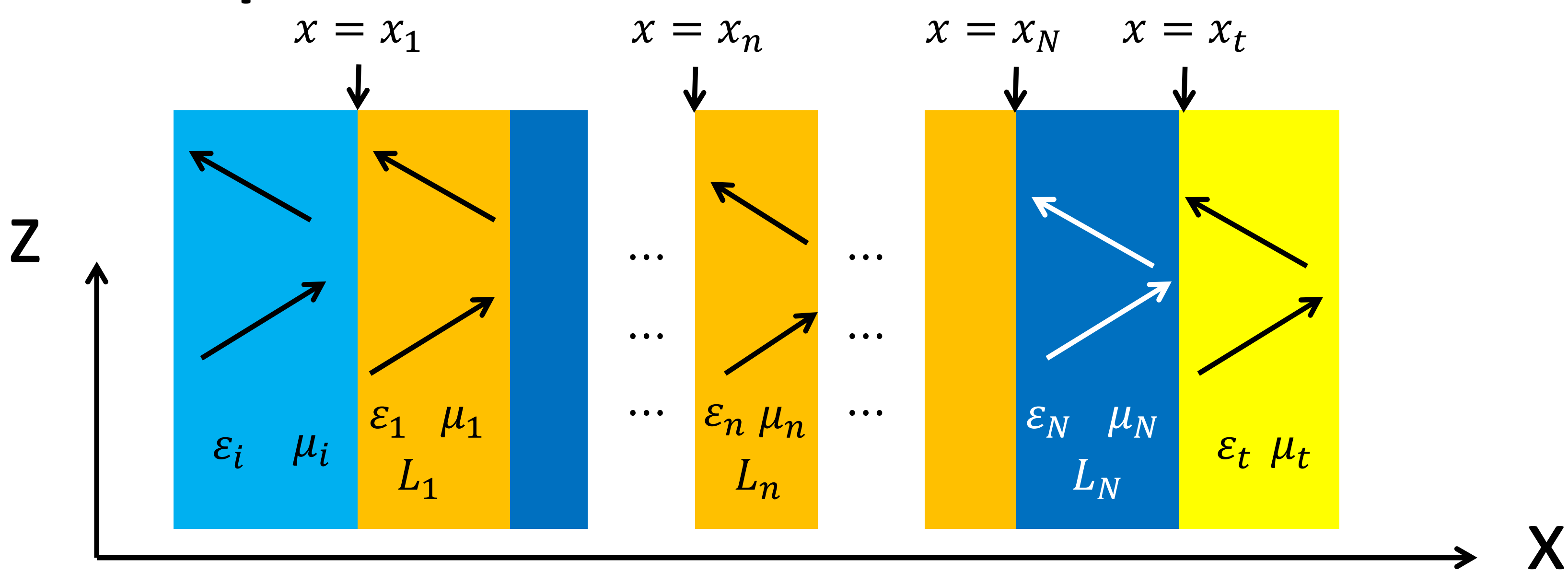
TM H_y E_x E_z

$$\vec{H}_n = e^{j(\omega t - \beta z)}\{C_n e^{-jk_{nx}(x-x_n)} + D_n e^{jk_{nx}(x-x_n)}\}\vec{e}_y$$

$$E_{nx} = \frac{\beta}{\varepsilon_n \omega} e^{j(\omega t - \beta z)}\{C_n e^{-jk_{nx}(x-x_n)} + D_n e^{jk_{nx}(x-x_n)}\}$$

$$E_{nz} = \frac{1}{j \varepsilon_n \omega} e^{j(\omega t - \beta z)}\{-jk_{nx} C_n e^{-jk_{nx}(x-x_n)} + jk_{nx} D_n e^{jk_{nx}(x-x_n)}\}$$

Comparison of TE and TM Cases



TE E_y H_x H_z

$$\begin{bmatrix} A_{n+1} \\ B_{n+1} \end{bmatrix} = T_n^{TE} \begin{bmatrix} A_n \\ B_n \end{bmatrix} = [D_{n+1}^{TE}]^{-1} D_n^{TE} P_n^{TE} \begin{bmatrix} A_n \\ B_n \end{bmatrix}$$

$$D_n^{TE} = \begin{bmatrix} 1 & 1 \\ \frac{k_{nx}}{\mu_n} & -\frac{k_{nx}}{\mu_n} \end{bmatrix}$$

$$P_n^{TE} = \begin{bmatrix} e^{-jk_{nx}L_n} & 0 \\ 0 & e^{jk_{nx}L_n} \end{bmatrix}$$

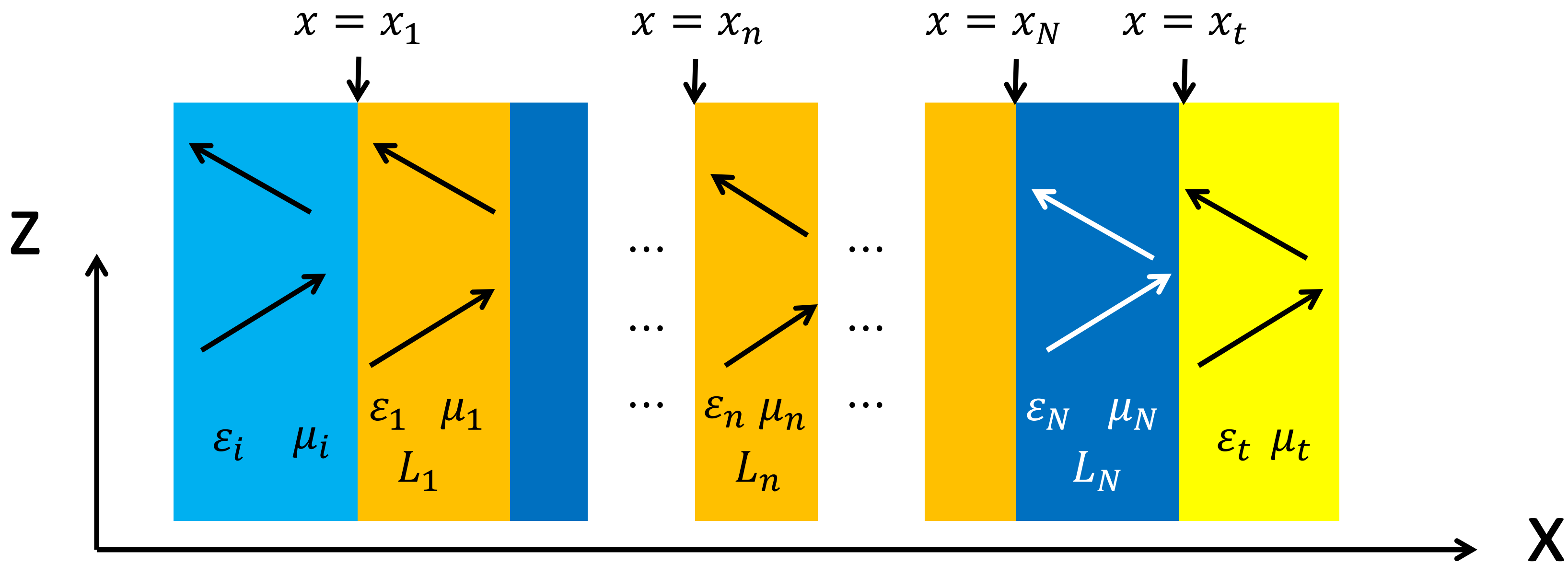
TM H_y E_x E_z

$$\begin{bmatrix} C_{n+1} \\ D_{n+1} \end{bmatrix} = T_n^{TM} \begin{bmatrix} C_n \\ D_n \end{bmatrix} = [D_{n+1}^{TM}]^{-1} D_n^{TM} P_n^{TM} \begin{bmatrix} C_n \\ D_n \end{bmatrix}$$

$$D_n^{TM} = \begin{bmatrix} 1 & 1 \\ \frac{k_{nx}}{\varepsilon_n} & -\frac{k_{nx}}{\varepsilon_n} \end{bmatrix}$$

$$P_n^{TM} = \begin{bmatrix} e^{-jk_{nx}L_n} & 0 \\ 0 & e^{jk_{nx}L_n} \end{bmatrix}$$

Comparison of TE and TM Cases



TE $\quad \begin{bmatrix} A_t \\ B_t \end{bmatrix} = T_{TE} \begin{bmatrix} A_i \\ B_i \end{bmatrix} \qquad T_{TE} = T_N^{TE} T_{N-1}^{TE} \cdots T_n^{TE} \cdots T_2^{TE} T_1^{TE} \left[(D_1^{TE})^{-1} D_i^{TE} \right]$

TM $\quad \begin{bmatrix} C_t \\ D_t \end{bmatrix} = T_{TM} \begin{bmatrix} C_i \\ D_i \end{bmatrix} \qquad T_{TM} = T_N^{TM} T_{N-1}^{TM} \cdots T_n^{TM} \cdots T_2^{TM} T_1^{TM} \left[(D_1^{TM})^{-1} D_i^{TM} \right]$

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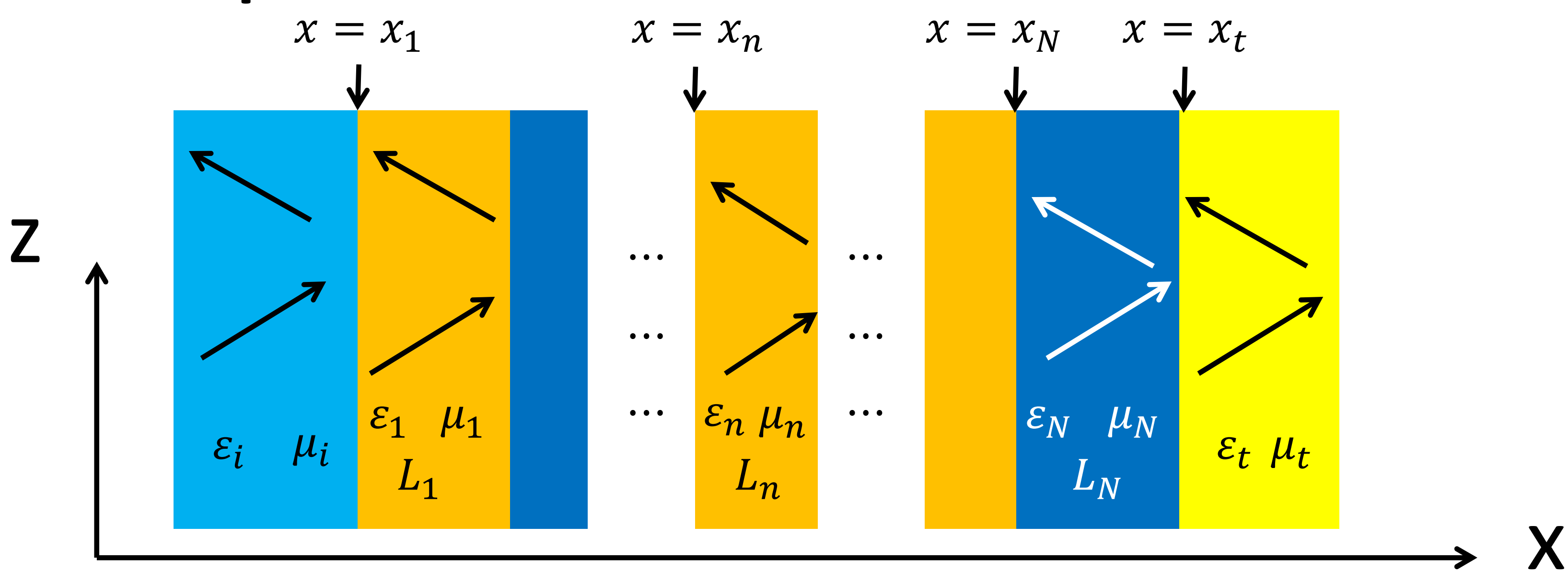

TE E_y H_x H_z

TM H_y E_x E_z

$$r = \frac{(T_{TE}^{-1})_{21}}{(T_{TE}^{-1})_{11}} \qquad R = \left|\frac{(T_{TE}^{-1})_{21}}{(T_{TE}^{-1})_{11}}\right|^2$$

$$t = \frac{1}{(T_{TE}^{-1})_{11}} \qquad T = \frac{\mu_i k_{tx}}{\mu_t k_{ix}} \frac{1}{|(T_{TE}^{-1})_{11}|^2}$$

$$r = \frac{(T_{TM}^{-1})_{21}}{(T_{TM}^{-1})_{11}} \qquad R = \left|\frac{(T_{TM}^{-1})_{21}}{(T_{TM}^{-1})_{11}}\right|^2$$

$$t = \frac{1}{(T_{TM}^{-1})_{11}} \qquad T = \frac{\varepsilon_i k_{tx}}{\varepsilon_t k_{ix}} \frac{1}{|(T_{TM}^{-1})_{11}|^2}$$