EE4620 Spectral Domain Methods in EM

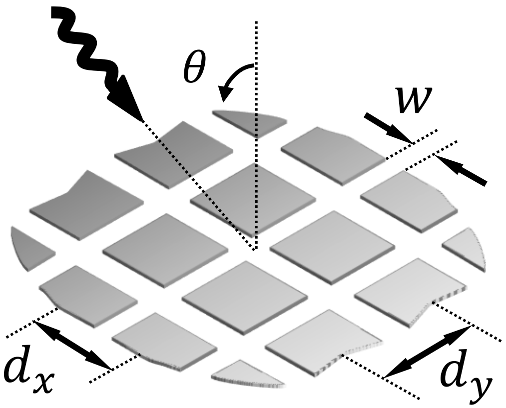
Lecture: Matlab Session on Artificial Dielectrics

TU Delft

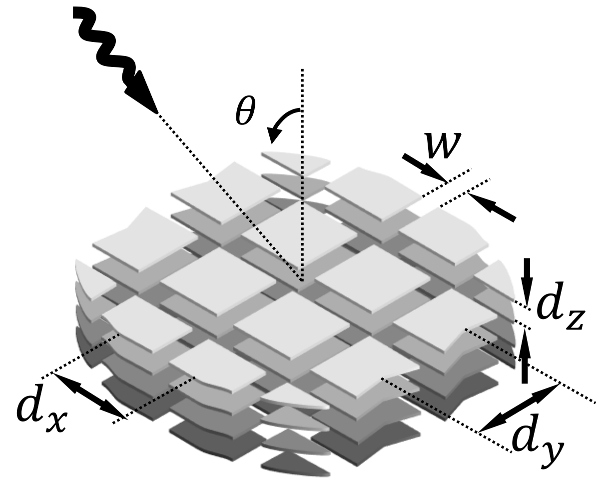
Problem

Implement the reflection and transmission coefficient of a plane wave impinging on

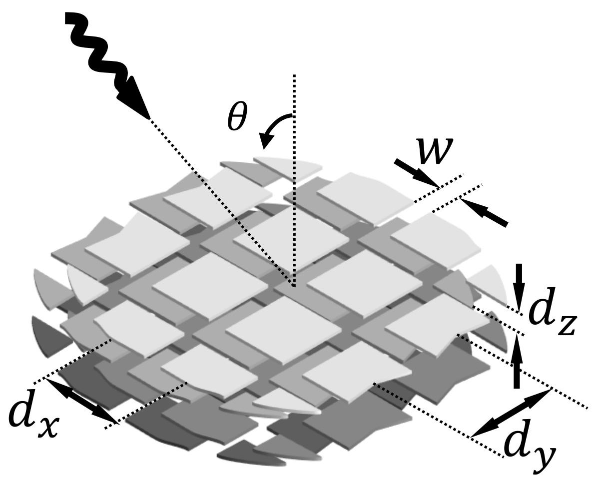
1. Single layer of sub-wavelength patches

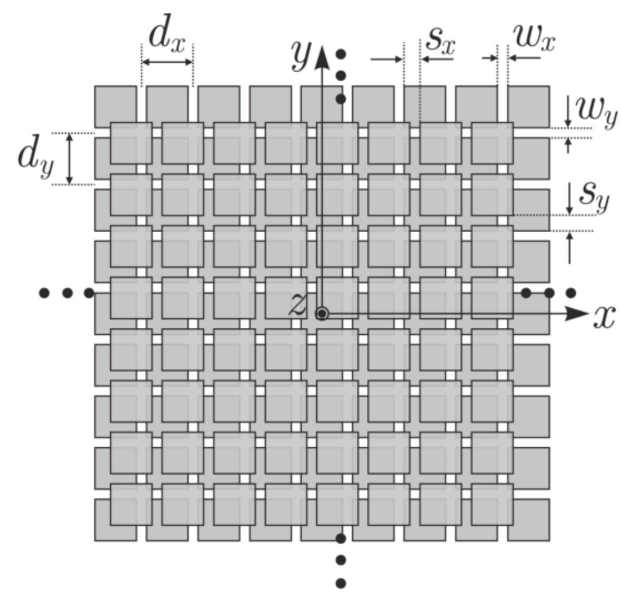


2. N-layer artificial dielectric (aligned)



3. N-layer artificial dielectric (alternate shift)



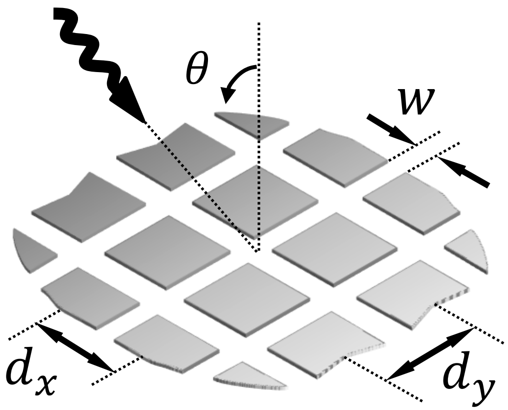


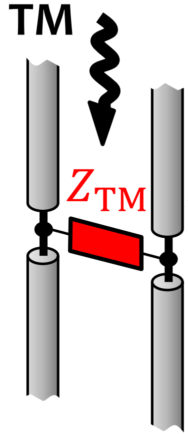
Problem 1

Single layer of sub-wavelength patches

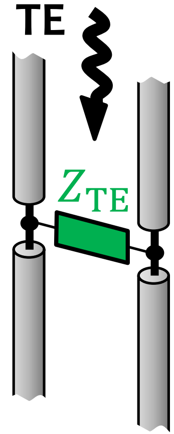
Susceptance

$$B \approx \frac{\omega \varepsilon_0 d_y}{\pi} \sum_{m \neq 0} \frac{\left|\mathrm{sinc}(\pi m w / d_y)\right|^2}{|m|}$$





$$Z_{\mathrm{TM}} = -\frac{j}{B}$$

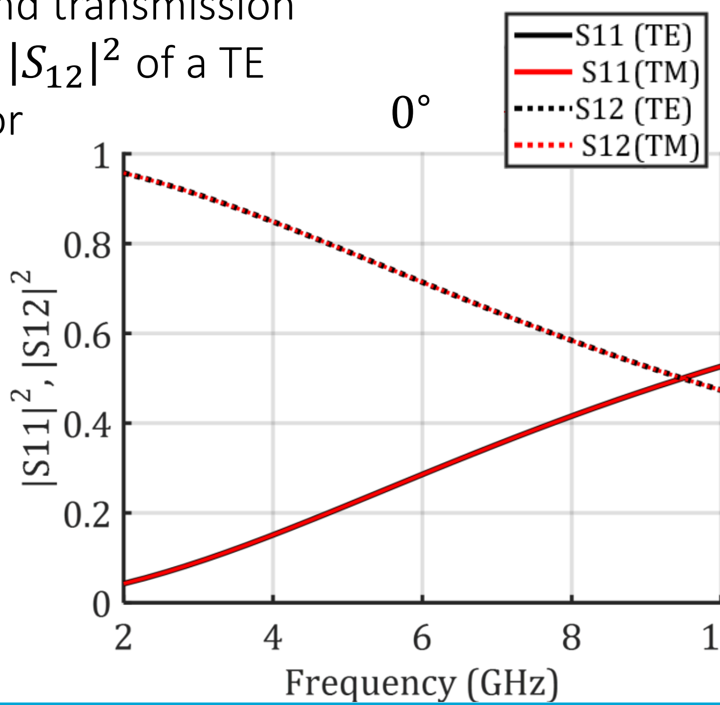


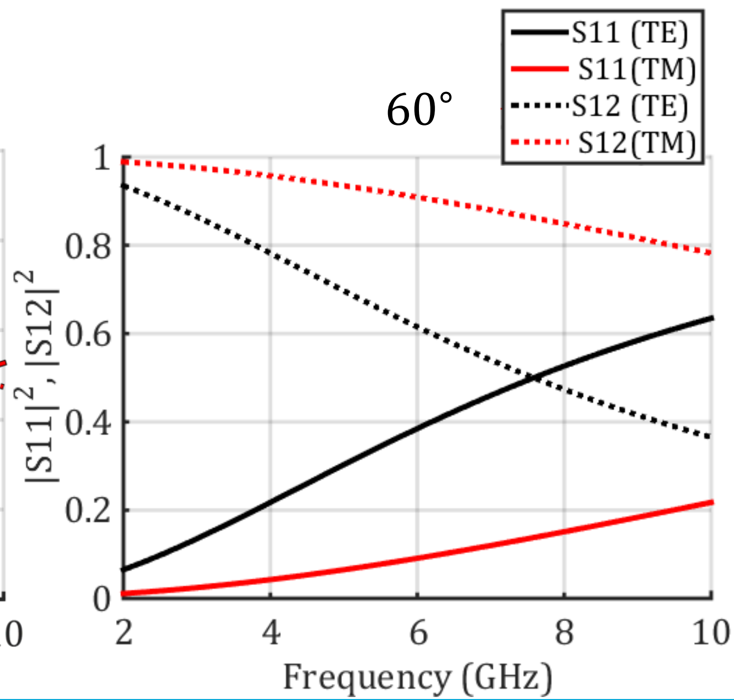
$$Z_{\mathrm{TE}} = -\frac{j}{B} \frac{1}{1 - \frac{\sin^2 \theta}{2}}$$

1. Plot the reflection and transmission coefficients $|S_{11}|^2$ and $|S_{12}|^2$ of a TE and TM plane waves for
- Normal incidence
- Incidence at 60°

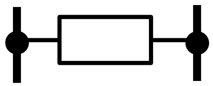
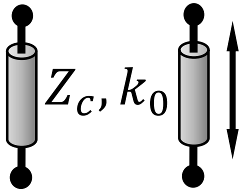
- Parameters

Freq. range: 2-10 GHz
$w = 0.01\lambda_0$
$d_x = d_y = 0.2\lambda_0$
λ_0 wavelength at 10 GHz





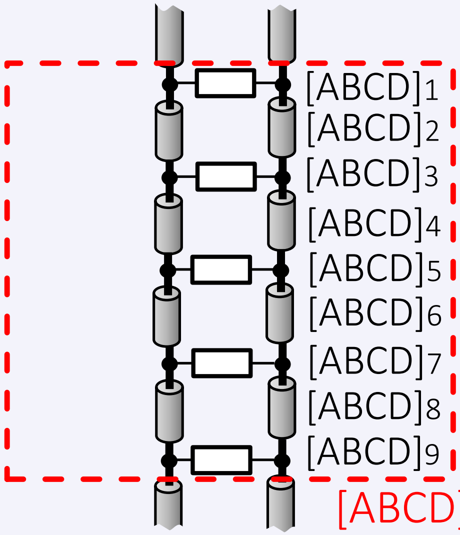
Reminder: ABCD Matrix, S-Matrix

		$\begin{bmatrix} A & B \\ C & D \end{bmatrix}$	$\begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$
Shunt impedance	$Z = 1/Y$ 	$\begin{bmatrix} 1 & 0 \\ Y & 1 \end{bmatrix}$	$S_{11} = \frac{-YZ_0}{2+YZ_0}$, $S_{12} = \frac{2}{2+YZ_0}$
Transmission line section	 Z_c, k_0 d_z	$\begin{bmatrix} \cos k_0 d_z & jZ_c \sin k_0 d_z \\ jY_c \sin k_0 d_z & \cos k_0 d_z \end{bmatrix}$	

General conversion

	ABCD
S_{11}	$\frac{A + B/Z_0 - CZ_0 - D}{A + B/Z_0 + CZ_0 + D}$
S_{12}	$\frac{2(AD - BC)}{A + B/Z_0 + CZ_0 + D}$
S_{21}	$\frac{2}{A + B/Z_0 + CZ_0 + D}$
S_{22}	$\frac{-A + B/Z_0 - CZ_0 + D}{A + B/Z_0 + CZ_0 + D}$

Z_0: normalization impedance

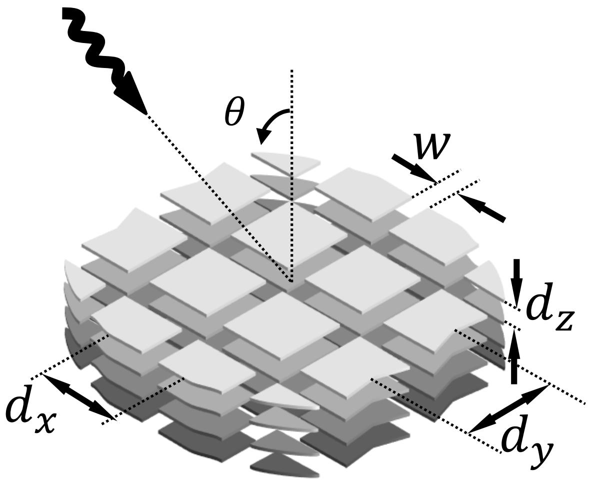


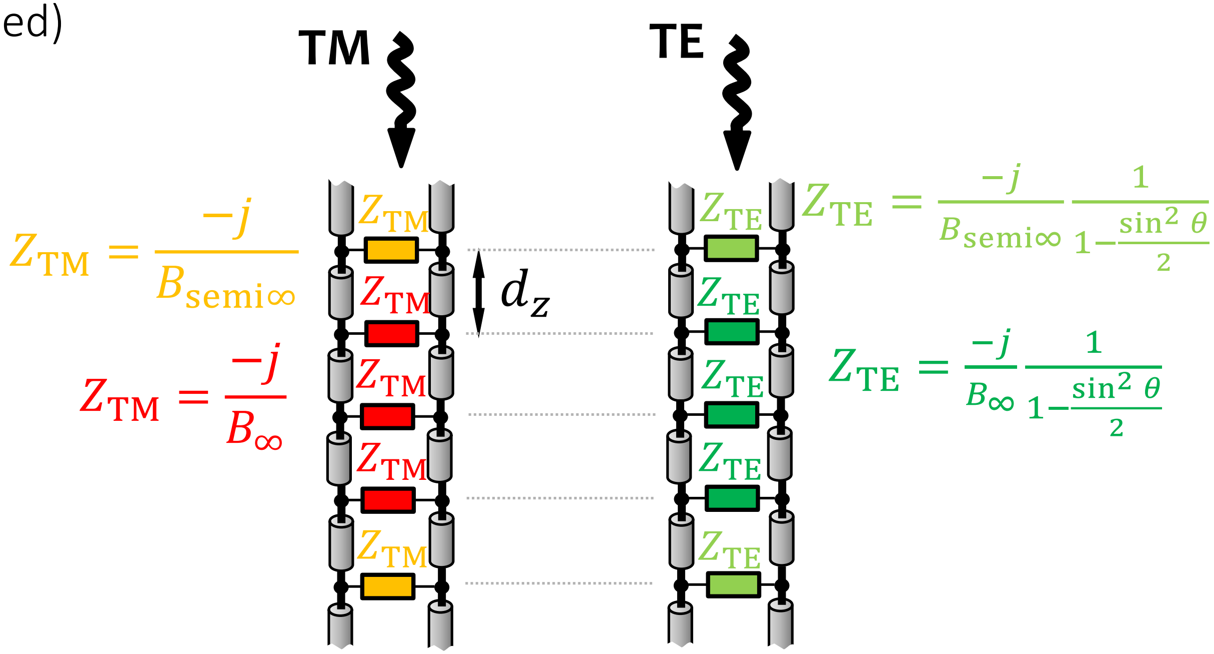
Advantage: total ABCD matrix is product of the ABCD matrixes of the single components

$$[ABCD]_{TOT} = \prod_{i=1}^{9} [ABCD]_i$$

Problem 2

N-layer artificial dielectric (aligned)





Susceptance

$$B_{\infty} \approx \frac{\omega\varepsilon_0 d_y}{\pi} \sum_{m\neq 0} \frac{\left|\mathrm{sinc}(\pi m w/d_y)\right|^2}{|m|} \times j\tan\left(\frac{-j\pi|m|d_z}{d_y}\right)$$

$$B_{\mathrm{semi}-\infty} \approx \frac{\omega\varepsilon_0 d_y}{\pi} \sum_{m\neq 0} \frac{\left|\mathrm{sinc}(\pi m w/d_y)\right|^2}{|m|} \times \left(\frac{1}{2} + \frac{j}{2}\tan\left(\frac{-j\pi|m|d_z}{d_y}\right)\right)$$

Problem 2

2. Plot the reflection and transmission coefficients $|S_{11}|^2$ and $|S_{12}|^2$ of a TE and TM plane waves for
- Normal incidence
- Incidence at $60°$

- Parameters

$N = 5$

Freq. range: 2-10 GHz

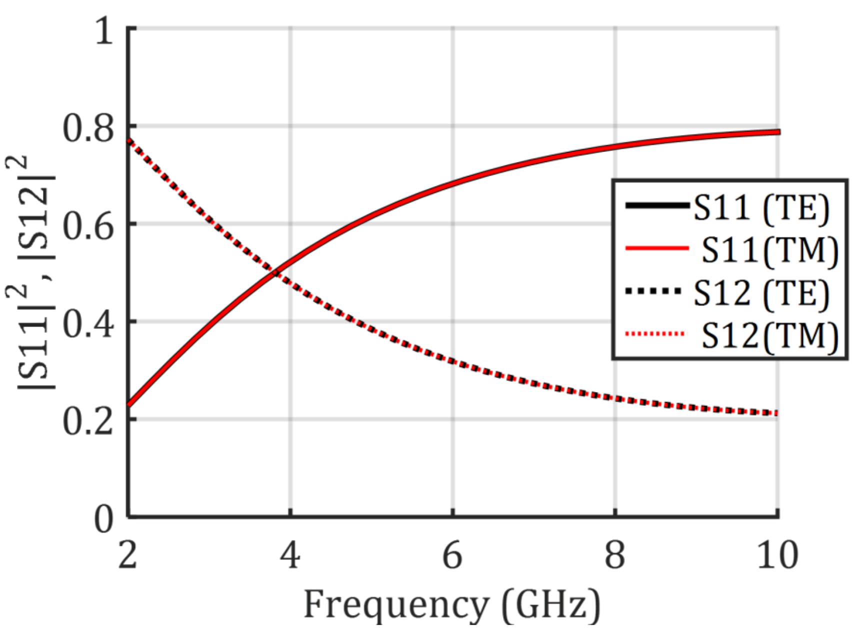
$w = 0.01\lambda_0$

$d_z = 0.01\lambda_0$

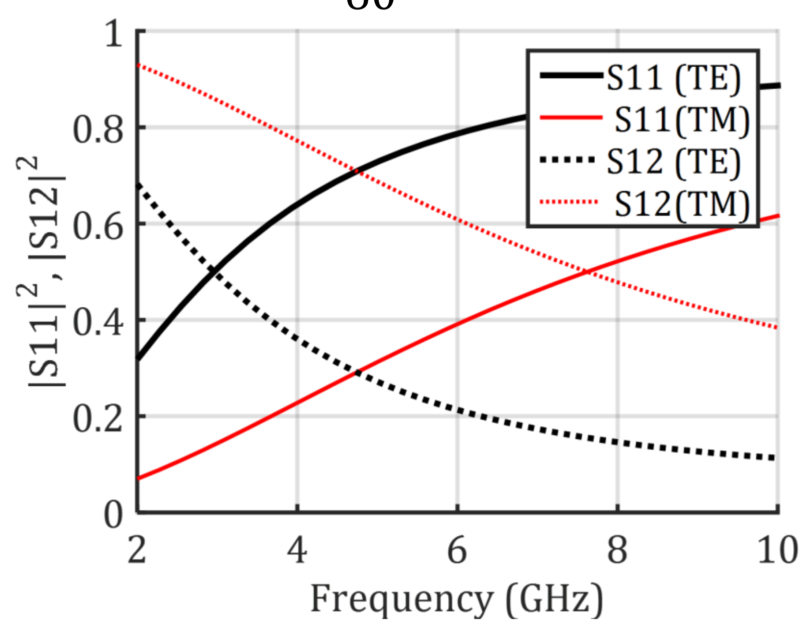
$d_x = d_y = 0.2\lambda_0$

λ_0 wavelength at 10 GHz

$0°$

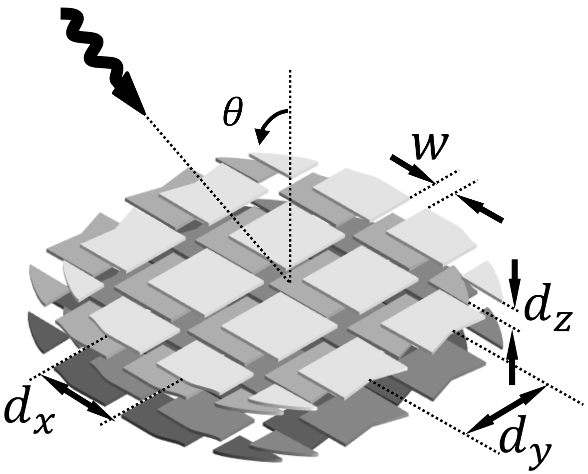


$60°$



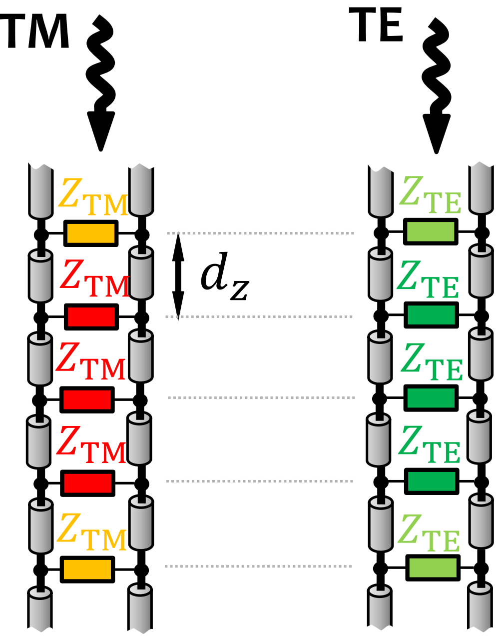
Problem 3

N-layer artificial dielectric (nonaligned)



$$Z_{\mathrm{TM}} = \frac{-j}{B_{\mathrm{semi}\infty}}$$

$$Z_{\mathrm{TM}} = \frac{-j}{B_{\infty}}$$



$$Z_{\mathrm{TE}} = \frac{-j}{B_{\mathrm{semi}\infty}} \frac{1}{1-\frac{\sin^2\theta}{2}}$$

$$Z_{\mathrm{TE}} = \frac{-j}{B_{\infty}} \frac{1}{1-\frac{\sin^2\theta}{2}}$$

Susceptance

$$B_{\infty} \approx \frac{k_0}{\zeta_0}\frac{d_y}{\pi}\sum_{m\neq 0}\frac{\left|\mathrm{sinc}(\pi m w_x/d_y)\right|^2}{|m|}\left(-j\cot\left(\frac{-j2\pi|m|d_z}{d_y}\right) + j\, e^{j2\pi m s_y/d_y}\csc\left(\frac{-j2\pi|m|d_z}{d_y}\right)\right)$$

$$B_{\mathrm{semi}\infty} \approx \frac{k_0}{\zeta_0}\frac{d_y}{\pi}\sum_{m\neq 0}\frac{\left|\mathrm{sinc}\left(\frac{\pi m w}{d_y}\right)\right|^2}{|m|}\left(\frac{1}{2} - \frac{j}{2}\cot\left(\frac{-j2\pi|m|d_z}{d_y}\right) + \frac{j}{2}e^{j2\pi m\frac{s_y}{d_y}}\csc\left(\frac{-j2\pi|m|d_z}{d_y}\right)\right)$$

Problem 3

3. Plot the reflection and transmission coefficients $|S_{11}|^2$ and $|S_{12}|^2$ of a TE and TM plane waves for

- Normal incidence
- Incidence at $60°$

- Parameters

$N = 2$

Freq. range: 2-10 GHz

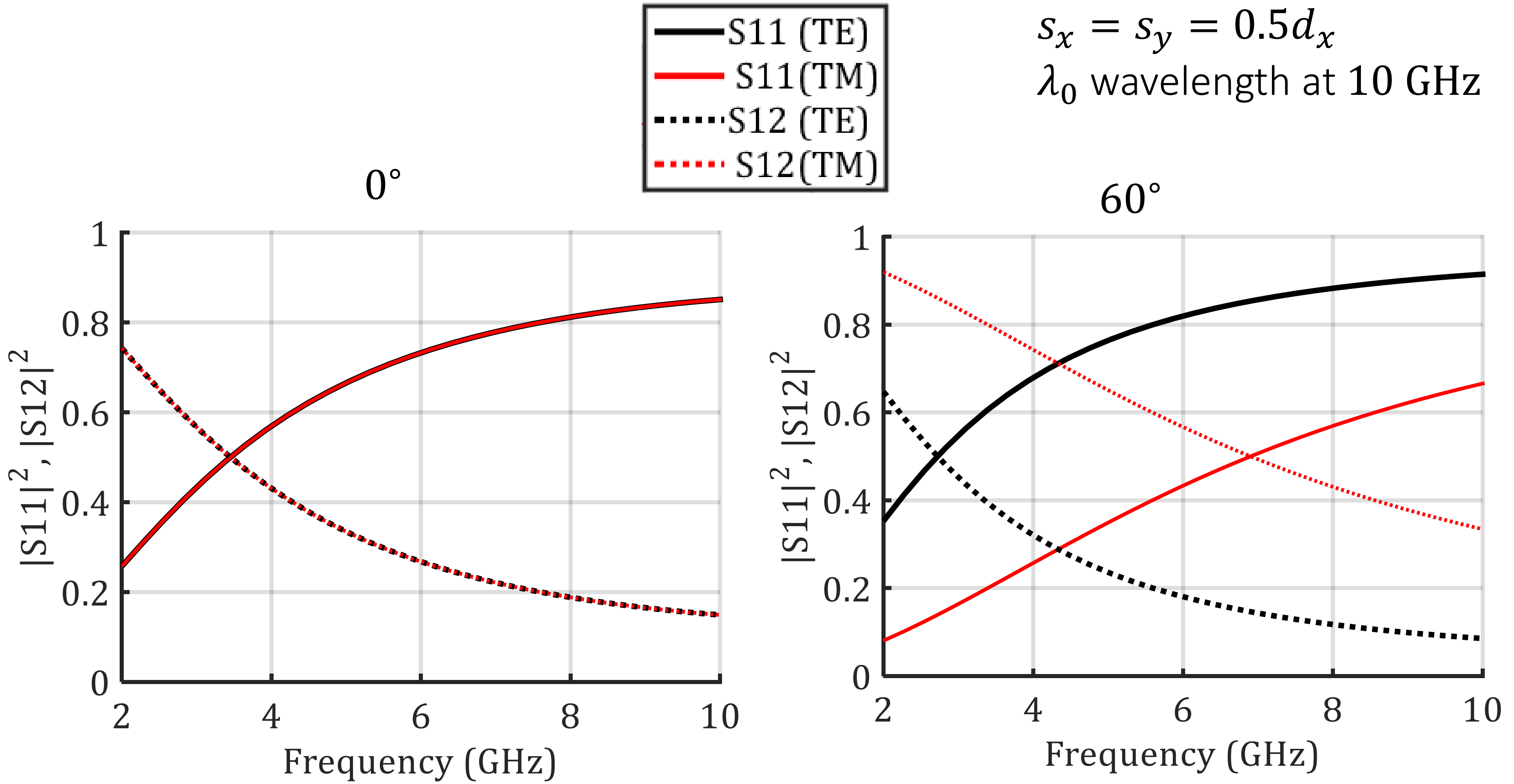
$w = 0.01\lambda_0$

$d_z = 0.02\lambda_0$

$d_x = d_y = 0.2\lambda_0$

$s_x = s_y = 0.5d_x$

λ_0 wavelength at 10 GHz



Behaves almost the same as 5 layers of aligned layers