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	Microwave Systems

$\mu_0 = 4\pi \times 10^{-7} \quad \varepsilon_0 = 8.8541\times 10^{-12}$

$\sigma(copper) = 5.8\times 10^{7}$ S/m

Transmission Lines (lossless)

$$V(z) = V_0^+ e^{-j\beta z} + V_0^- e^{+j\beta z}$$

$$I(z) = \frac{V_0^+}{Z_0} e^{-j\beta z} - \frac{V_0^-}{Z_0} e^{+j\beta z}$$

$$Z_0 = \frac{V_0^+}{I_0^+} = \sqrt{\frac{L}{C}}$$

$$\gamma = \alpha + j\beta = j\beta = j\omega\sqrt{LC}\ ,\ \beta = \omega\sqrt{\mu\varepsilon}$$

Wavelength $\lambda = \frac{2\pi}{\beta}$, phase velocity $\upsilon_p = \frac{\omega}{\beta}$

For coaxial line $Z_0 = \sqrt{\frac{\mu}{\varepsilon}} \frac{\ln(b/a)}{2\pi}$

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0},\ RL = -20\log|\Gamma|,\ SWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

$$T = 1+\Gamma,\quad IL = -20\log|T|$$

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)}$$

$$\Gamma(-l) = \Gamma(0) e^{-j2\beta l}$$

Average power $P_{ave} = \frac{1}{2}\mathrm{Re}\left(V_{in} I_{in}^*\right)$

$\alpha_d = \frac{k \tan\delta}{2}$ for TEM lines, $\quad \alpha_{dB} = 20\ \log e^{\alpha l}$

Microwave Networks

$Vn = Vn^+ + Vn^-$

$In = In^+ - In^-$

[b] = [S] [a], [V] = [Z] [I], [I] = [Y] [V]

$$Z_{ij} = \left.\frac{V_i}{I_j}\right|_{I_k = 0\ for\ k\neq j},\quad Y_{ij} = \left.\frac{I_i}{V_j}\right|_{V_k = 0\ for\ k\neq j},\quad S_{ij} = \left.\frac{V_i^-}{V_j^+}\right|_{V_k^+=0 \text{ for } k\neq j} = \left.\frac{b_i}{a_j}\right|_{a_k=0 \text{ for } k\neq j}$$

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix}\begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

Impedance Matching: L Networks

For $\boxed{R_L > Z_0}$

$$B = \frac{X_L \pm \sqrt{R_L/Z_0}\sqrt{R_L(R_L - Z_0) + X_L^2}}{R_L^2 - X_L^2},\quad X = \frac{1}{B} + \frac{X_L Z_0}{R_L} - \frac{Z_0}{BR_L}$$

For $\boxed{R_L < Z_0}$

$$B = \pm\sqrt{R_L(Z_0 - R_L)} - X_L,\quad X = \pm\frac{\sqrt{(Z_0 - R_L)/R_L}}{Z_0}$$

Multisection Transformer

$$\Gamma_n = \frac{Z_{n+1} - Z_n}{Z_{n+1} + Z_n}$$

For n even:

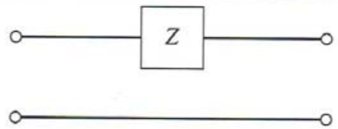
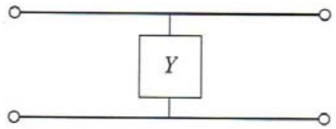
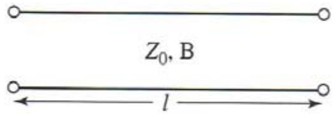
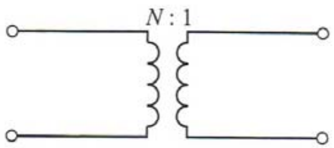
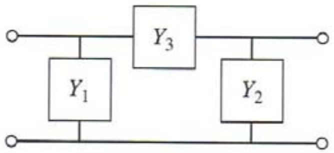
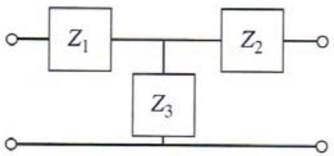
$$\Gamma(\theta) = 2e^{-jN\theta}\begin{bmatrix} \Gamma_0 \cos N\theta + \Gamma_1 \cos(N-2)\theta + ... \\ +\Gamma_n \cos(N-2n)\theta + ... + \frac{1}{2}\Gamma_{\frac{N}{2}} \end{bmatrix}$$

For n odd

$$\Gamma(\theta) = 2e^{-jN\theta}\begin{bmatrix} \Gamma_0 \cos N\theta + \Gamma_1 \cos(N-2)\theta + ... \\ +\Gamma_n \cos(N-2n)\theta + ... + \Gamma_{\frac{N-1}{2}} \cos\theta \end{bmatrix}$$

S_{11}	$\dfrac{A + B/Z_0 - CZ_0 - D}{A + B/Z_0 + CZ_0 + D}$
S_{12}	$\dfrac{2(AD - BC)}{A + B/Z_0 + CZ_0 + D}$
S_{21}	$\dfrac{2}{A + B/Z_0 + CZ_0 + D}$
S_{22}	$\dfrac{-A + B/Z_0 - CZ_0 + D}{A + B/Z_0 + CZ_0 + D}$
A	$\dfrac{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}}{2S_{21}}$
B	$Z_0 \dfrac{(1 + S_{11})(1 + S_{22}) - S_{12}S_{21}}{2S_{21}}$
C	$\dfrac{1}{Z_0} \dfrac{(1 - S_{11})(1 - S_{22}) - S_{12}S_{21}}{2S_{21}}$
D	$\dfrac{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}}{2S_{21}}$

TABLE 4.1 The *ABCD* Parameters of Some Useful Two-Port Circuits

Circuit	*ABCD* Parameters	
	$A = 1$ $C = 0$	$B = Z$ $D = 1$
	$A = 1$ $C = Y$	$B = 0$ $D = 1$
	$A = \cos \beta\ell$ $C = jY_0 \sin \beta\ell$	$B = jZ_0 \sin \beta\ell$ $D = \cos \beta\ell$
	$A = N$ $C = 0$	$B = 0$ $D = \dfrac{1}{N}$
	$A = 1 + \dfrac{Y_2}{Y_3}$ $C = Y_1 + Y_2 + \dfrac{Y_1 Y_2}{Y_3}$	$B = \dfrac{1}{Y_3}$ $D = 1 + \dfrac{Y_1}{Y_3}$
	$A = 1 + \dfrac{Z_1}{Z_3}$ $C = \dfrac{1}{Z_3}$	$B = Z_1 + Z_2 + \dfrac{Z_1 Z_2}{Z_3}$ $D = 1 + \dfrac{Z_2}{Z_3}$