

## ELEC 353 Formula Sheet

### Constants

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

### Maxwell's Equations

$$\nabla \cdot \bar{D} = \rho_v \quad \nabla \times \bar{H} = \bar{J} + \frac{\partial \bar{D}}{\partial t}$$

$$\nabla \cdot \bar{B} = 0 \quad \nabla \times \bar{E} = -\frac{\partial \bar{B}}{\partial t}$$

### Time-Domain Transmission Lines

$$\frac{\partial v}{\partial z} = -\ell \frac{\partial i}{\partial t}$$

$$\frac{\partial i}{\partial z} = -c \frac{\partial v}{\partial t}$$

$$R_c = \sqrt{\frac{\ell}{c}}$$

$$u = \frac{1}{\sqrt{\ell c}}$$

### Reflection at a load:

$$\Gamma = \frac{R_L - R_c}{R_L + R_c}$$

### Transmission from line #1 onto line #2:

$$T_{12} = \frac{2R_{c2}}{R_{c1} + R_{c2}}$$

### Sinusoidal Steady State

$$\frac{dV}{dz} = -(r + j\omega\ell)I$$

$$\frac{dI}{dz} = -(g + j\omega c)V$$

$$\gamma = \alpha + j\beta = \sqrt{(r + j\omega\ell)(g + j\omega c)}$$

$$Z_0 = \sqrt{\frac{r + j\omega\ell}{g + j\omega c}}$$

With the generator at  $z = 0$  and the load at  $z = L$ :

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

$$V^- = V^+ \Gamma_L e^{-2j\beta L}$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = |\Gamma_L| e^{j\phi}$$

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta L}{Z_0 + jZ_L \tan \beta L}$$

### Single-Stub Matching Formulas

$$\text{Line length: } L = \frac{\phi - \cos^{-1}(-|\Gamma_L|)}{2\beta}$$

$$\text{Stub length: } L_s = \frac{1}{\beta} \cot^{-1} \left[ \frac{\pm 2|\Gamma_L|}{\sqrt{1 - |\Gamma_L|^2}} \right]$$

### Time-Harmonic Maxwell's Equations

$$\nabla \cdot \bar{E} = \frac{\rho_v}{\epsilon} \quad \nabla \times \bar{H} = (\sigma + j\omega\epsilon)\bar{E}$$

$$\nabla \cdot \bar{H} = 0 \quad \nabla \times \bar{E} = -j\omega\mu\bar{H}$$

$$E_x(z) = E_x^+ e^{-\gamma z} + E_x^- e^{\gamma z}$$

$$\gamma = \alpha + j\beta = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)}$$

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}}$$

### Reflection

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\tau = \frac{2\eta_2}{\eta_2 + \eta_1}$$

### Transmission through a Wall

$$T = \frac{4\eta_0\eta_w e^{-j\beta_w d}}{(\eta_0 + \eta_w)^2 - (\eta_0 - \eta_w)^2 e^{-2j\beta_w d}}$$

### Antennas

$$\text{Hertzian Dipole: } E_\theta = \frac{j\eta_0\beta I_0 \ell}{4\pi} \sin\theta \frac{e^{-j\beta r}}{r}$$

### Ideal Dipole of arm length $h$ :

$$E_\theta(\theta) = \frac{jI_0\eta_0}{2\pi} F(\theta) \frac{e^{-j\beta r}}{r}$$

$$F(\theta) = \frac{\cos(\beta h \cos\theta) - \cos(\beta h)}{\sin\theta}$$

### Half-wave Dipole Antenna

$$P_{rad} = 36.5 I_0^2$$

### Friis Transmission Equation

$$P_R = \left( \frac{\lambda}{4\pi R} \right)^2 G_R G_T P_{in}$$