TLWA : U1, U2 – Formula list.

1. transmission line eqns.

$\gamma = \alpha + j\beta = \sqrt{(R+j\omega L)(G+j\omega C)}$

λ (wavelength) $= \frac{2\pi}{\beta}$

v_p (phase velocity) $= \frac{\omega}{\beta} = \lambda \cdot f$

Z_0 (characteristic impedance) $= \sqrt{\frac{R+j\omega L}{G+j\omega C}} = R_0 + jX_0$.

2. wave propagation on a transmission line

$\gamma = \alpha + j\beta = \sqrt{(R+j\omega L)(G+j\omega C)}$

$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}}$

$\lambda = \frac{2\pi}{\beta}$ $\quad v_p = \frac{\omega}{\beta}$

3. lossless line

$R = G = 0$.

$\alpha = 0$

$\gamma = \alpha + j\beta = j\omega\sqrt{LC}$.

$Z_0 = \sqrt{\frac{L}{C}}$

$\lambda = \frac{2\pi}{\omega\sqrt{LC}}$.

$v_p = \frac{1}{\sqrt{LC}}$

4. terminated lossless transmission line.

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}.$$

#. $\Gamma = 0 \rightarrow$ no reflected wave $\rightarrow Z_L = Z_0$.

$$P_{avg} = \frac{1}{2} \cdot \frac{|V_0^+|^2}{Z_0} \cdot \left[1 - |\Gamma|^2\right].$$

RL (return loss) $= -20\log|\Gamma|$ dB.

IL (insertion loss) $= -20\log|\Gamma|$ dB.

$V_{max} = |V_0^+| \cdot (1 + |\Gamma|)$.

$V_{min} = |V_0^-| \cdot (1 - |\Gamma|)$

$$SWR = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|}. \quad ; \quad 1 \leq SWR \leq \infty.$$

$$Z_{in} = Z_0 \left[\frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}\right]$$

i). tx line is short circuited.

$Z_L = 0$.

$SWR = \infty$.

$\Gamma = -1$.

$V = 0$ at load

$I = max$.

$Z_{in} = jZ_0 \tan\beta l$

$Z_{in} = 0$

$Z_{in} = \infty$ at $l = \frac{\lambda}{2}$

ii). tx line is open circuited.

$Z_L = \infty$.

$SWR = \infty$.

$\Gamma = 1$

$V = max$

$I = 0$ at load

$Z_{in} = -jZ_0 \cot\beta l$

$Z_{in} = Z_L$ at $l = \frac{\lambda}{2}$

$Z_{in} = \frac{Z_0^2}{Z_L}$ at $l = \frac{\lambda}{4} + \frac{n\lambda}{2}$

5. S-parameters.

$V^+ \rightarrow$ incident voltage

$V^- \rightarrow$ reflected voltage

$$P = \frac{1}{2} |V_{max}| \cdot |I_{min}|$$

$$|V_{max}| = |V^+| + |V^-|$$

$$|I_{min}| = \frac{1}{Z_0}(|V^+| - |V^-|)$$

$$P = \frac{1}{2}\left[\left(\frac{|V^+|}{\sqrt{Z_0}}\right)^2 - \left(\frac{|V^-|}{\sqrt{Z_0}}\right)^2\right]$$

$$S = \frac{\text{reflected wave}}{\text{incident wave}} = \frac{b}{a}$$

$$|a| = \frac{|V^+|}{\sqrt{Z_0}}$$

$$|b| = \frac{|V^-|}{\sqrt{Z_0}}$$

$$V_{incident} = \frac{1}{2}(V + IZ_0)$$

$$V_{reflected} = \frac{1}{2}(V - IZ_0)$$

$$S = \frac{V - IZ_0}{V + IZ_0}$$

6. solution of equation of rectangular coordinates.

$\gamma_g^2 = \gamma^2 + k_c^2$; $k_c^2 = \sqrt{k_x^2 + k_y^2}$.

i). no propagation of EM wave.

$\gamma_g = 0$.

$f_c = \frac{c}{2\pi}\sqrt{k_x^2 + k_y^2}$

$k_c^2 = \omega^2 \mu \varepsilon$

ii). propagation of wave

$\gamma_g^2 = \sqrt{k_c^2 - \omega^2 \mu \varepsilon}$

$\gamma_g = \frac{\omega}{c}\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$

> . $f > f_c$, EM wave will propagate.

iii). attenuation of wave.

$\gamma_g = \sqrt{k_c^2 - \omega^2 \mu \varepsilon}$

$\gamma_g = \frac{\omega}{c}\sqrt{\left(\frac{f_c}{f}\right)^2 - 1}$

> $f < f_c$, wave will be attenuated.

7. salient features of TE wave.

① cut off freq. $(f_c) = \frac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$ $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

②. phase constant $\beta = \omega\sqrt{\mu\varepsilon}\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$

③. min. cut off freq $(f_{c_{10}}) = \frac{c}{2\pi} \cdot \left(\frac{\pi}{a}\right)$

#. TE_{10} mode is dominant mode.

④. wave impedance (Z_{TE}) = $\dfrac{1}{c\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

$$Z_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \quad ; \quad \eta = \sqrt{\frac{\mu}{\varepsilon}}.$$

⑤. guide wavelength (λg) = $\dfrac{c}{f\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

⑥. phase velocity (V_p) = $\dfrac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

8. salient features of TM mode.

①. min. cut off freq. ($f_{c\,min}$) = $\dfrac{c}{2\pi}\sqrt{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}$

②. guided wavelength (λg) = $\dfrac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

③. cut off freq. (f_c) = $\dfrac{c}{2\pi}\sqrt{\left(\frac{\pi}{a}\right)^2+\left(\frac{\pi}{b}\right)^2}$

~~TE~~ TM11 mode is dominant mode.

$$\beta = \sqrt{k^2-\left(\frac{m\pi}{a}\right)^2-\left(\frac{n\pi}{b}\right)^2}$$

④. wave impedance (Z_{TM}) = $\dfrac{\beta}{\omega\varepsilon}$

④. phase velocity (V_p) = $\dfrac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

#. TM00, TM01, TM10 modes do not exist.