※ 考生請注意：本試題 ☑可 □不可 使用計算機

* $\varepsilon_0 = 10^{-9}/36\pi$; $\mu_0 = 4\pi \times 10^{-7}$; $\eta_0 = 120\pi$

1. The Helmholtz's equations in a **source-free lossy medium** $(\varepsilon, \mu, \sigma)$ are as follows.

$$\nabla^2 \bar{E} + k_c^2 \bar{E} = 0$$
$$k_c = \sqrt{-j\omega\mu(\sigma + j\omega\varepsilon)} = \omega\sqrt{\mu\varepsilon(1+\tfrac{\sigma}{j\varepsilon\omega})} = \omega\sqrt{\mu\varepsilon_c},$$
$$\varepsilon_c = \text{equivalent complex-permittivity}$$

(a) Determine the approximated **intrinsic (wave) impedance** η_c of a TEM wave in **a good conductor** $(\sigma/\varepsilon\omega >> 1)$.(10%)

(b) From (a) explain that E- and H-field of a TEM wave in a good conductor have **a phase difference of 45°**.(5%)

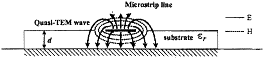
2. A 50-Ω microstrip line is on a substrate with $\varepsilon_r = 4$ and $d = 8$ μm at $f = 60$ GHz

(a) For a simplest **pure TEM-wave approximation**, determine the required line width w, guided wavelength λ & wave velocity v_p in the microstrip line. (5%)

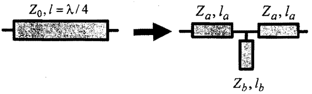
(b) By using the **quasi-TEM-wave approximation**, determine the guided wavelength λ_{eff} and wave velocity v_p in the microstrip line. (5%)

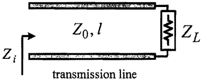
* in (b), use $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1+12(d/W)}}$ and the line width w from (a)

(c) Explain why the microstrip line can not support **pure TEM-wave.** (5%)



3. It can be proven that a $\lambda/4$ transmission line can be replaced by a **cascade** of two series shorter transmission lines (Z_a, l_a) with a *shunt* open-circuited short transmission line (Z_b, l_b) as shown in the figure. Derive the <u>two relation formulas</u> between Z_0 and (Z_a, Z_b, l_a, l_b). **(20%)**





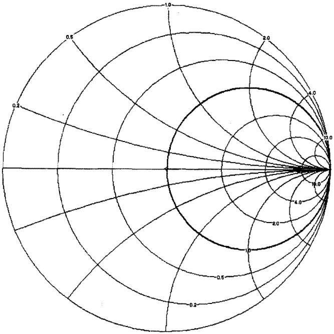
transmission line

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

※ 考生請注意：本試題 ☑可 □不可 使用計算機

4. Plot the normalized impedance point (to 50 Ω) in the Smith Chart and the corresponding SWR circles. (15%)
(a) $Z_L = 50\ \Omega$; (b) $Z_L = 0\ \Omega$; (c) $Z_L = 75 + j25\ \Omega$; (d) $Z_L = 10 - j5\ \Omega$

* Draw the Smith Chart and figures approximately.



5. (a) Determine the **TE$_{10}$-mode impedance** looking into a 20-cm-long section of a short-circuited air-filled WR90 waveguide (cut-off frequency = 6.56 GHz) operating at 10 GHz. **(10%)**

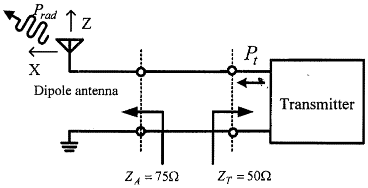
$$Z_{TE} = \eta_0 \Big/ \sqrt{1-(f_c/f)^2} \qquad \lambda_g = \lambda_0 \Big/ \sqrt{1-(f_c/f)^2}$$

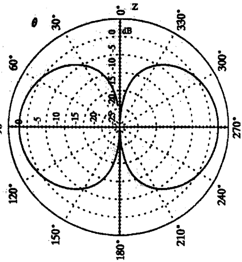
(b) Explain why the waveguide phase velocity is higher than the free-space wave velocity ? **(5%)**

$$u_p = f \times \lambda_g \left(= f \times \lambda_0 \Big/ \sqrt{1-(f_c/f)^2} \right) > u_{free-space} (= f \times \lambda_0)$$

※ 考生請注意：本試題 ☑可 □不可 使用計算機

6. As shown in the following figures, let the transmitter output power is $P_t = 1$ W and the dipole-antenna input and transmitter output impedance are shown in the figure ($f = 1$GHz).
   (a) Calculate the diopole-antenna radiation power P_{rad} in dBm. (10%)
   (b) From the antenna (directive gain) pattern, calculate the **radiation power density** (p_{av}) and **E-filed strength** in the direction of $\theta = 30°$ and distance $r = 100$ m. (10%)





Half-wavelength Dipole Antenna E-Plane Directive Gain Pattern