* **Useful constants** :

$\varepsilon_0 = 10^{-9}/(36\pi)$ (F/m); $\mu_0 = 4\pi \times 10^{-7}$ (H/m); $\sqrt{\mu_0/\varepsilon_0} = 120\pi$ (Ω)

1. **Maxwell's Equations and Wave Equations :**
   (a) Write Maxwell's equations in a **conductive medium** (μ, ε, σ) with the impressed source $\vec{J}$. (6%)
   (b) Write the expression of the complex permittivity ε_c from (a). (3%)
   (c) Indicate which term in (a) is the ***displacement current density*** and briefly explain the physical meaning of the displacement current. (6%)
   (d) The inhomogeneous wave equations of the E and H fields can be derived from (a) as follows.

$$\left(\nabla^2 - \mu\varepsilon_c \frac{\partial^2}{\partial t^2}\right)\begin{Bmatrix}\vec{E}\\ \vec{H}\end{Bmatrix} = \begin{Bmatrix}\nabla\rho/\varepsilon + \mu\partial\vec{J}/\partial t\\ -\nabla\times\vec{J}\end{Bmatrix}$$

   Derive the time-harmonic wave equation (Helmholtz equation). (6%)
   (e) Write the <u>definition</u> and <u>expression</u> of the intrinsic impedance η_c of a uniform plane wave in the conductive medium. (4%)

2. A Hertzian electric dipole antenna of current I and length l is located along the z-axis. The radiation far-zone field can be derived as follows.

$$\vec{E}^r = \hat{\theta}\eta\frac{jkIl}{4\pi}\frac{e^{-jkr}}{r}\sin\theta \qquad \vec{H}^r = \hat{\phi}\frac{kIl}{4\pi}\frac{e^{-jkr}}{r}\sin\theta$$

   (a) Determine the time-average power density. (3%)
   (b) Determine the radiation resistance of the Hertzian electric dipole. (5%)
   Note : $\int_0^{2\pi}\sin^3\theta d\theta = 4/3$
   (c) Show how to arrange two Hertzian electric dipoles to produce a circularly polarized wave (either RHCP or LHCP) <u>in the x direction</u>. Draw a figure of the arrangement and indicate the necessary conditions. (7%)

(背面仍有題目,請繼續作答)

3. **Waveguide Problem**

A 10-GHz signal is coupled to a 1-m-long waveguide that has dimensions of a = 2 cm, b = 1 cm. The output end of the waveguide is loaded in 200+j100 Ω.

(a) Determine the wavelength, frequency, and waveguide impedance Zg of the lowest-frequency signal that will propagate down the waveguide. (Note: You have to <u>derive the formulas</u> of the above quantities from the following waveguide-mode field formulas first.) (10%)

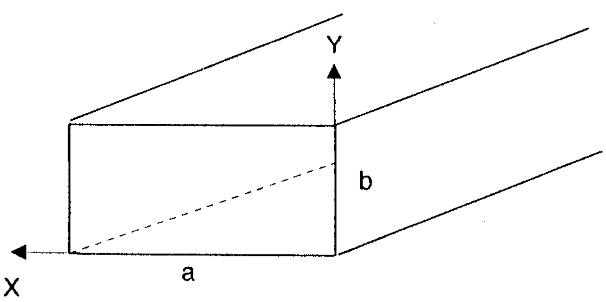
(b) The VSWR of the signal in the waveguide (loaded in 200 +j100 Ω).(4%)

(c) Write the expression and plot the cross-sectional E and H field distribution of the dominate mode. (4%)

(d) Prove that the E field of (c) satisfy the boundary condition.(4%)

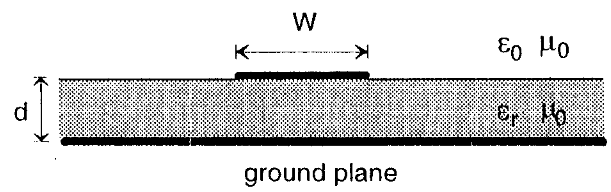
(e) Determine the surface currents on the waveguide wall (y = 0) of the dominate mode from the H field of (c).(4%)

(f) Use Smith chart and results of (a) to determine the impedance seen at the input end of the waveguide. (9%)



Waveguide TM mode fields	Waveguide TE mode fields
$E_z^0(x,y) = E_0 \sin(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)$	$H_z^0(x,y) = H_0 \cos(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)$
$E_x^0(x,y) = -\frac{\gamma}{h^2}(\frac{m\pi}{a})E_0 \cos(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)$	$E_x^0(x,y) = \frac{j\omega\mu}{h^2}(\frac{n\pi}{b})H_0 \cos(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)$
$E_y^0(x,y) = -\frac{\gamma}{h^2}(\frac{n\pi}{b})E_0 \sin(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)$	$E_y^0(x,y) = -\frac{j\omega\mu}{h^2}(\frac{m\pi}{a})H_0 \sin(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)$
$H_x^0(x,y) = \frac{j\omega\varepsilon}{h^2}(\frac{n\pi}{b})E_0 \sin(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)$	$H_x^0(x,y) = \frac{\gamma}{h^2}(\frac{m\pi}{a})H_0 \sin(\frac{m\pi}{a}x)\cos(\frac{n\pi}{b}y)$
$H_y^0(x,y) = -\frac{j\omega\varepsilon}{h^2}(\frac{m\pi}{a})E_0 \cos(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)$	$H_y^0(x,y) = \frac{\gamma}{h^2}(\frac{n\pi}{b})H_0 \cos(\frac{m\pi}{a}x)\sin(\frac{n\pi}{b}y)$
$\gamma = j\beta = j\sqrt{\omega^2\mu\varepsilon - (\frac{m\pi}{a})^2 - (\frac{n\pi}{b})^2}$	$h^2 = (\frac{m\pi}{a})^2 + (\frac{n\pi}{b})^2$

4. A microstrip transmission line is shown in the following figure.
   (a) Explain why the microstrip line can not support a pure TEM wave.(4%)
   (b) Draw a figure to illustrate an approximated E and H field distribution over the cross section of the microstrip line for quasi-TEM wave approximation.(3%)
   (c) Write an approximated simple formula of the characteristic impedance (Zo) and the guided wavelength (λ_g)of a microstrip line.(3%)

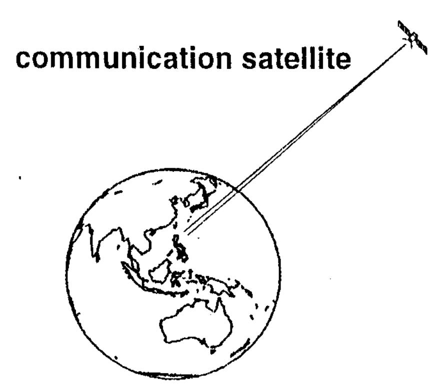


5. A communication satellite is in a synchronous orbit 36,000 km above the earth. The satellite transmitter power is 100 W and the satellite antenna with a gain 30 dB and radiation efficiency 0.6 at 20 GHz. The earth station receiver with an antenna gain 40 dB and radiation efficiency 0.6 receives the satellite transmitted signal.
   (a) Determine the effectively isotropically radiated power (EIRP) of the satellite antenna in terms of dBw.(5%)
   (b) Determine the time-average power density of the satellite antenna radiated wave at the location of the earth station. (5%)
   (c) Determine the received power of the earth station antenna (assuming a matched load and no polarization mismatch).(5%)

* **Radio communication link**: *Friis power transmission formula* $\frac{P_L}{P_{rad}} = \frac{G_t \eta_t G_r \eta_r \lambda^2}{(4\pi r)^2}$

P_{rad} = radiated power from the antenna, P_L = received power to the matched load

η_t (η_r) = transmitting (receiving) antenna radiation efficiency



The Smith Chart

NAME	TITLE	DWG. NO.
SMITH CHART FORM 82-BSPR(9-66)	KAY ELECTRIC COMPANY, PINE BROOK, N.J. © 1966. PRINTED IN U.S.A.	DATE

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