* **Useful constants :**

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

1. **Maxwell's Equations : (30%)**

   (a) Write down Maxwell's equations in a lossless medium ( $\mu$, $\varepsilon$) with the impressed sources ($\rho_i$, $\bar{J}_i$).

   (b) Indicate which term in (a) is the ***displacement current density*** and briefly explain the physical meaning of the displacement current.

   (c) Derive the inhomogeneous wave equations of the E field from (a).
   Note: $\nabla \times \nabla \times \bar{E} = \nabla(\nabla \cdot \bar{E}) - \nabla^2 \bar{E}$

   (d) Derive the time-harmonic wave equation (Helmholtz equation) of (c).

   (e) By defining the scalar and vector potentials ($\Phi$, $\bar{A}$) and using the Lorentz condition, the time-harmonic wave equations of (E, H) fields can be transformed to the wave equations of($\Phi$, $\bar{A}$). It can be derived that

   $$\Phi = \frac{1}{4\pi\varepsilon}\int_V \frac{\rho_i\, e^{-jkR}}{R}\, dv' \qquad \bar{A} = \frac{\mu}{4\pi}\int_V \frac{\bar{J}_i\, e^{-jkR}}{R}\, dv$$

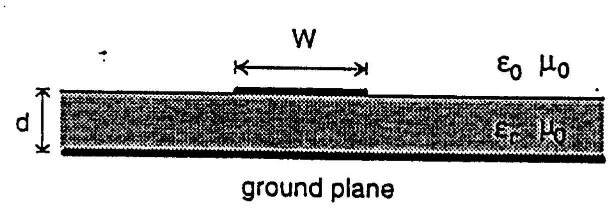
   Write down the Lorentz condition and explain that the Lorentz condition is consistent with the continuity equation.

2. A microstrip transmission line is shown in the following figure. (15 %)

   (a) Explain why the microstrip line can not support a <u>pure TEM guided wave</u>.

   (b) If the substrate is very thin, we can assume that the quasi-TEM wave propagates in a transmission line which means that the fields are essentially the same as those of the static case. Draw a figure to illustrate an approximated E and H field distribution over the cross section of the microstrip line.

   (c) Write the simple form formula of the characteristic impedance (Zo) and the guided wavelength ($\lambda_g$)of a microstrip line.




**Microstrip Transmission Line**

3. **Waveguide Problem**

A 10-GHz RF 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 285 Ω. Determine the following: (30%)

(a) Wavelength and frequency of the lowest-frequency RF signal that will propagate down the waveguide

(b) The waveguide modes, if any, that will propagate in the waveguide and plot the cross-sectional E field distribution

(c) The guide wavelength $\lambda g$ and waveguide impedance Zg of the mode

(d) The VSWR of the RF signal in the waveguide (loaded in 285 Ω)

(e) The impedance seen at the input end of the waveguide

(f) Briefly explain the physical meaning of the waveguide modes. (Note : Do not just discuss what are the TE and TM modes. Try to explain the mode from the solution point-of-view of the wave equations in a waveguide.)

4. A communication satellite is in a synchronous orbit 36,000 km above the earth. The satellite transmitter power is 10 W and the satellite antenna with a gain 30 dB and radiation efficiency 0.7 at 10 GHz radiates a circularly polarized (CP) wave. The earth station receiver with an antenna gain 40 dB and radiation efficiency 0.6 receives the satellite transmitted signal. (25%)

(a) Determine the time-average power density of the satellite antenna radiated wave at the location of the earth station.

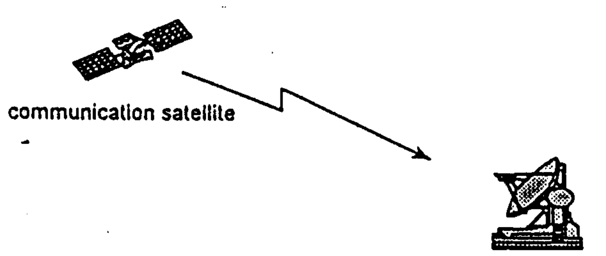
(b) Determine the received power of the earth station antenna (assuming a matched load and no polarization mismatch).

(c) Let the θ component of the far-zone E field of the satellite antenna radiated wave be ($f(\theta,\phi)$ is the antenna pattern function)

$$E_\theta = E_0\left(\frac{e^{-j\beta r}}{4\pi r}\right)f(\theta,\phi)$$

Write all other components of the E and H fields (either right-hand or left-hand circular polarization).

(d) Determine the $E_\theta$ field intensity from (a) and (c).

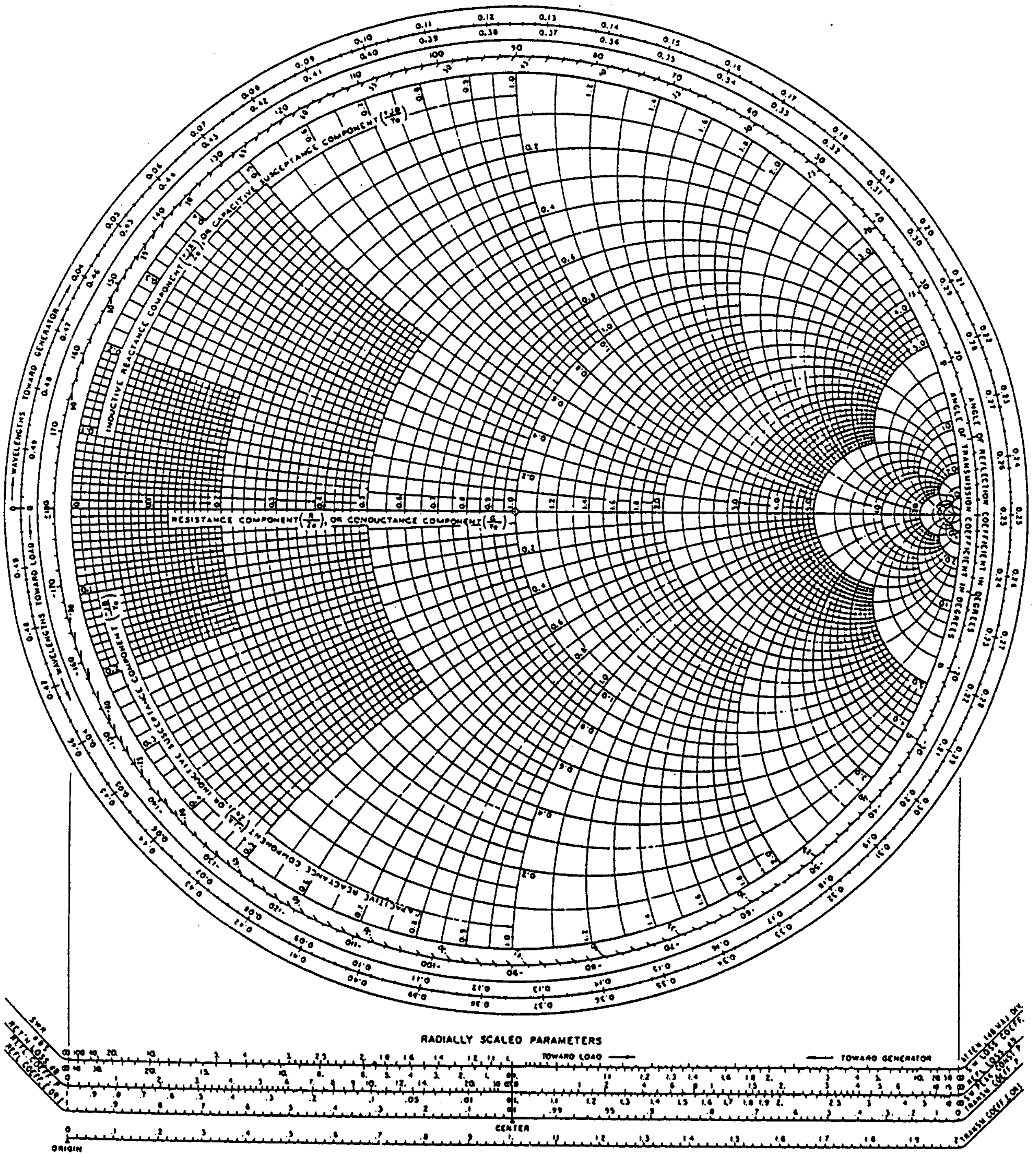



* Communication link power transmission formula

$$\frac{P_L}{P_{rad}} = \frac{G_t\eta_t G_r\eta_r\lambda^2}{(4\pi r)^2}$$

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

$\eta_t$ ($\eta_r$) = transmitting (receiving ) antenna radiation efficiency




. The Smith Chart.