MACHAKOS UNIVERSITY

University Examinations for 2020/2021

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF COMPUTING AND INFORMATION TECHNOLOGY

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION AND INFORMATION TECHNOLOGY)

SPH 444: SATELLITE COMMUNICATION

DATE: 16/8/2021 **TIME: 2:00 – 4:00 PM**

INSTRUCTIONS

Answer Question One and Any Other Two Questions

QUESTION ONE-COMPULSORY (30 MARKS)

a) State Kepler's first law and list the three parameters associated with this law. (4 marks)

b) Define the following terms: (4 marks)
   i) Apogee and Perigee
   ii) Prograde and retrograde orbits
   iii) Argument of Perigee
   iv) Line of Apsides

c) The classical development for the determination of rain attenuation on a transmitted radiowave is based on three assumptions describing the nature of radiowave propagation and precipitation. Outline these assumptions. (3 marks)

d) An antenna has noise a temperature of 35^0 K and is matched into a receiver which has a noise temperature of 100^0 K. Calculate: (4 marks)
   i) Noise power density
   ii) The noise power for a bandwidth of 36 MHz

e) Write a note on Equivalent Isotropic Radiated Power (EIRP). Hence, a satellite downlink is at 12 GHz operate with a transmit power of 6 W and an antenna gain if 48.2 dB. Calculate the EIRP in dBW. (3marks)

f) Determine the angle of tilt required for polar mount used with an earth station at latitude 49^0 North. Assume a spherical Earth of mean radius 6371 km, and ignore the earth station latitude. (3 marks)

g) How does a satellite go through an eclipse? Explain with appropriate diagram. (6 marks)

h) Why is it more prudent to launch a satellite from a point closer to an equator? (3 marks)

QUESTION TWO (20 MARKS)

a) What is antenna misalignment loss? Propose a solution to overcome these losses. (10 marks)

b) Explain why large earth stations are used for commercial communications for geostationary orbits? (2 marks)

Hence,

c) A geostationary satellite is located 90^0 W. Calculate the azimuth angle for an Earth station antenna located at latitude 35^0 W and longitude 100^0 W. (8 marks)

QUESTION THREE (20 MARKS)

a) The relative impact of rain conditions on the transmitted signal depends on the spatial structure of rain. Discuss two types of rain structure that are important in the evaluation of rain effects on earth-space communications. (10 marks)

b) Discuss channel reservation scheme for satellite communication. (10 marks)

QUESTION FOUR (20 MARKS)

a) Derive the link power budget equation. (6 marks)

Hence,

b) A satellite link operating at 14 GHz has receiver feeder losses of 1.5 dB and a free-space loss of 207 dB. The atmospheric absorption loss is 0.5 dB and the antenna pointing loss is 0.5 dB. Depolarization losses may be neglected. Calculate the total link loss for a clear – sky condition. (4 marks)

c) Discuss the phenomenon of Sun Transit Outage experienced in satellite communication. (10 marks)

QUESTION FIVE (20 MARKS)

a) Explain the technique of TDMA. How is TDMA network advantageous over FDMA network? (10 marks)

b) Discuss using relevant diagrams how a GEO is launched using a transfer orbit to the GEO. (10 marks)

USEFUL INFORMATION

Constants

$c = 3\times10^{8}$ m/s

$\epsilon_o = 8.85\times10^{-12}$ F/m

$\mu_o = 4\pi\times10^{-7}$ H/m

$\epsilon = \epsilon_o \epsilon_r$

$\mu = \mu_o \mu_r$

Maxwell's Equations

Differential form:

$$\nabla \times \vec{\varepsilon} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

$$\nabla \cdot \vec{D} = \rho$$

$$\nabla \cdot \vec{B} = 0$$

Integral Form:

$$\oint_c \vec{\varepsilon}.d\vec{l} = -\frac{\partial}{\partial t}\int_s \vec{B}.d\vec{s} - \int_s \vec{M}.d\vec{s}$$

$$\oint_c \vec{H}.d\vec{l} = \frac{\partial}{\partial t}\int_s \vec{D}.ds + \int_s \vec{J}.d\vec{s}$$

$$\oint_S \vec{B}.d\vec{s} = 0$$

$$\oint_S \vec{D}.d\vec{s} = \int_V \rho\, dv = Q$$

Lorentz's Force Equation

$\vec{F} = q(\vec{\varepsilon} + \vec{U}\times\vec{B})$ Newtons

Continuity Equation

$$\nabla \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$$

General **Boundary conditions** between two media

$$\vec{a}_n \times (\vec{\varepsilon}_2 - \vec{\varepsilon}_1) = 0$$

$$\vec{a}_n \times (\vec{H}_2 - \vec{H}_1) = \vec{J}_s$$

$$\vec{a}_n \cdot (\vec{D}_2 - \vec{D}_1) = \rho_s$$

$$\vec{a}_n \cdot (\vec{B}_2 - \vec{B}_1) = 0$$

Plane Wave Propagation

Poynting's Vector

$\vec{S} = \vec{\varepsilon} \times \vec{H}$

The Wave equation

$$\nabla^2 \vec{\varepsilon} = \mu\sigma \frac{\partial \vec{\varepsilon}}{\partial t} + \mu \epsilon \frac{\partial^2 \vec{\varepsilon}}{\partial t^2}$$

$$\nabla^2 \vec{H} = \mu\sigma \frac{\partial \vec{H}}{\partial t} + \mu \epsilon \frac{\partial^2 \vec{H}}{\partial t^2}$$

Propagation constant

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

Intrinsic impedance

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

$$v_p = \frac{\omega}{\beta} \qquad \lambda_g = \frac{\lambda_o}{\sqrt{\in_r}}$$

$$\beta = \frac{2\pi}{\lambda_g} \qquad v_g = \frac{d\omega}{d\beta}$$

Phasor Poynting Vector $\hat{S} = \hat{E} \times \hat{H}^*$

Average Power Flow $S_{av} = \frac{1}{2}\mathrm{Re}\left\{\hat{E} \times \hat{H}^*\right\}$

Skin Depth $\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$

Lossless medium	Good dielectric	Good Conductor
$\alpha = 0$	$\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu}{\in}}$	$\alpha \cong \sqrt{\frac{\omega\mu\sigma}{2}}$
$\beta = \omega\sqrt{\mu \in}$	$\beta \cong \omega\sqrt{\mu \in}$	$\beta \cong \sqrt{\frac{\omega\mu\sigma}{2}}$
$v_p = 1/\sqrt{\mu \in}$	$v_p \cong 1/\sqrt{\mu \in}$	$v_p \cong \sqrt{\frac{2\omega}{\mu\sigma}}$
$\eta = \sqrt{\frac{\mu}{\in}}$	$\eta \cong \sqrt{\frac{\mu}{\in}}$	$\hat{\eta} = \sqrt{\frac{\omega\mu}{\sigma}}\angle 45^\circ$

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

$$V(z) = V_o^+\left[e^{-j\beta z} + \Gamma e^{j\beta z}\right]$$

$$I(z) = \frac{V_o^+}{Z_o}\left[e^{-j\beta z} - \Gamma e^{j\beta z}\right]$$

$$\Gamma = \frac{V_o^-}{V_0^+} = \frac{Z_L - Z_o}{Z_L + Z_o}$$

RL = -20log|Γ| dB

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$$

$$Z_{in} = Z_o \frac{Z_L + jZ_o \tan\beta l}{Z_o + jZ_L \tan\beta l}$$

EMC

$$E_{out} = \tau_{eff} E_{in}$$

$$\tau_{eff} \approx \frac{1}{1 + {z_0}/{(2R_s)}} \qquad where\ \tau_{eff} = \frac{\tau_{12}\tau_{23}e^{-\gamma L}}{1 - \rho_{21}\rho_{23}e^{-2\gamma L}}$$

$$where\ R_s = \frac{1}{\sigma L} = surface\,resis\tan ce$$

$$the\,sheet$$

For Electric fields through a shielding block

For very thin films L<<skin depth

TABLE 4-2-2 *p*th ZEROS OF $J_n(K_c a)$ FOR TM_{np} MODES

p	$n =$ 0	1	2	3	4	5
1	2.405	3.832	5.136	6.380	7.588	8.771
2	5.520	7.106	8.417	9.761	11.065	12.339
3	8.645	10.173	11.620	13.015	14.372	
4	11.792	13.324	14.796			

TABLE 4-2-1 pth ZEROS OF $J'_n(K_c a)$ FOR TE_{np} MODES

p	$n =$ 0	1	2	3	4	5
1	3.832	1.841	3.054	4.201	5.317	6.416
2	7.016	5.331	6.706	8.015	9.282	10.520
3	10.173	8.536	9.969	11.346	12.682	13.987
4	13.324	11.706	13.170			

$$(\vec{A}\times\vec{B})\cdot\vec{C}=(\vec{B}\times\vec{C})\cdot\vec{A}=(\vec{C}\times\vec{A})\cdot\vec{B}$$

$$\vec{A}\times(\vec{B}\times\vec{C})=(\vec{A}\cdot\vec{C})\vec{B}-(\vec{A}\cdot\vec{B})\vec{C}$$

$$\nabla\cdot(\vec{A}+\vec{B})=\nabla\cdot\vec{A}+\nabla\cdot\vec{B}$$

$$\nabla(\mathbf{V}+\mathbf{W})=\nabla\mathbf{V}+\nabla\mathbf{W}$$

$$\nabla\times(\vec{A}+\vec{B})=\nabla\times\vec{A}+\nabla\times\vec{B}$$

$$\nabla\cdot(\mathbf{V}\vec{A})=\vec{A}\cdot\nabla\mathbf{V}+\mathbf{V}\nabla\cdot\vec{A}$$

$$\nabla\times(\mathbf{V}\vec{A})=\nabla\mathbf{V}\times\vec{A}+\mathbf{V}\nabla\times\vec{A}$$

$$\nabla(\vec{A}\cdot\vec{B})=(\vec{A}\cdot\nabla)\vec{B}+(\vec{B}.\nabla)\vec{A}+\vec{A}\times(\nabla\times\vec{B})+\vec{B}\times(\nabla\times\vec{A})$$

$$\nabla\times(\vec{A}\times\vec{B})=\vec{A}\nabla\cdot\vec{B}-\vec{B}\nabla\cdot\vec{A}+(\vec{B}\cdot\nabla)\vec{A}-(\vec{A}\cdot\nabla)\vec{B}$$

$$\nabla\cdot\nabla\mathbf{V}=\nabla^2\mathbf{V}$$

$$\nabla\cdot\nabla\times\vec{A}=0$$

$$\nabla\times\nabla\mathbf{V}=0$$

$$\nabla\times\nabla\times\vec{A}=\nabla(\nabla\cdot\vec{A})-\nabla^2\vec{A}$$

CONDUCTIVITIES OF MATERIALS

Material	Conductivity, S/m	Material	Conductivity, S/m
Copper (annealed)	5.8×10^7	Steel	$0.5\text{–}1.0 \times 10^7$
Aluminum	3.54×10^7	Water (distilled)	2×10^{-4}
Silver	6.14×10^7	Sea water	3–5
Nickel	1.28×10^7	Quartz (fused)	$< 2 \times 10^{-17}$

DIELECTRIC CONSTANTS OF MATERIALS

Material	*Frequency, MHz*	ϵ'/ϵ_0	*Loss tangent* ϵ''/ϵ'
Polystyrene	3,000	2.54	0.00025–0.0016
Polystyrene (foam)	3,000	1.05	0.00003
Lucite	10,000	2.56	0.005
Teflon	10,000	2.08	0.00037
Fused quartz	10,000	3.78	0.0001
Ruby mica	3,000	5.4	0.0003
Titanium dioxide	10,000	90	0.002
Mahogany wood	10,000	1.7	0.021

SKIN DEPTH IN COPPER

Frequency, Hz	10	60	10^2	10^3	10^4	10^8
Skin depth δ_s, cm	2.08	0.85	0.66	0.208	6.6×10^{-2}	6.6×10^{-4}

$\delta_s = \sqrt{2/\omega\mu\sigma} = 6.6 f^{-1/2}$ cm for copper ($\sigma = 5.8 \times 10^7$ S/m).