VIT

Vellore Institute of Technology

(Deemed to be University under section 3 of the UGC Act, 1956)

Reg. No. : 21BEC1851

Final Assessment Test (FAT) - May 2024

Programme	B.Tech.	Semester	WINTER SEMESTER 2023 - 24
Course Title	ANTENNA AND MICROWAVE ENGINEERING	Course Code	BECE305L
Faculty Name	Prof. Richards Joe Stanislaus	Slot	G1+TG1
		Class Nbr	CH2023240503163
Time	3 Hours	Max. Marks	100

General Instructions:

- Write only Register Number in the Question Paper where space is provided (right-side at the top) & do not write any other details.

Section - I

Answer all questions (7 X 10 Marks = 70 Marks)

01. **(a)** Write the expression for [10]

i) Average power radiated P_{rad} in terms of radiation density W_{rad} . **(2 marks)**

ii) Infinitesimal area of a sphere dS as a function of the variables of spherical coordinates. **(2 marks)**

iii) elemental solid angle $d\Omega$ as a function of the variables of spherical coordinates. **(1 mark)**

(b) The maximum radiation intensity of a 90% efficient antenna is 300 mW/unit solid angle. When the input power is 150 mW, find:

i) Directivity (in dB) **(3 marks)**

ii) Gain (in dB) **(2 marks)**

02. Two identical X band rectangular horns with aperture dimensions of 5.6 cm and 7.4 cm and each with a gain of 16 dB (over isotropic) operate at 12 GHz. The two antennas are used as transmitting and receiving antennas. For an input power of 300 mW, the VSWR of each antenna is 1.2, the conductor-dielectric efficiency is 100%, and the antennas have polarization loss factor of 1. If the two horn antennas are spearated by a distance of 40m in air, find the following: [10]

a) Wavelength of operation (meters) **(2 marks)**

b) Dimensionless gain of the horn **(1 mark)**

c) Maximum power received by the receiving horn antenna. **(5 marks)**

d) If the beam solid angle of an antenna is 1.2 steradians, what is the antenna's directivity (in dB) **(2 marks)**?

03. a) Obtain the excitation coefficients of the individual elements of a 7 element binomial array? **(4 marks)** [10]

b) Describe the disadvantages of Binomial array excitation when compared to the array when excited with Chebyshev coefficients. **(2 marks)**

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c) A three element array of isotropic sources has the identical magnitude excitation with progressive phase excitation as $\beta = -\pi/2$. Find the array factor and the first null angle. **(4 marks)**

04. **(a)** Draw and briefly discuss the J-E curve (or I-V) characteristics of Gunn diode. **(6 marks)** [10]
(b) Write the doping profiles of the following diodes: **(4 marks)**
(i) IMPATT (ii) TRAPATT (iii) BARITT

05. a) Design a stepped imepdace low-pass filter having a maximally flat response and a cutoff frequency of 4 GHz (3 dB). It is desired to have more than 20 dB insertion loss at 6.4 GHz. The filter impedance is 30 Ω, the highest practical line impedace is 100 Ω with the lowest is 20 Ω. List the values of βl for the reactive elements of the low pass filter. **(8 marks).** [10]
b) Draw a sample plot of Attenuation (dB) against frequency (GHz) in X axis for the above design and mark the above mentioned frequency points and attenuation. **(2 marks)**

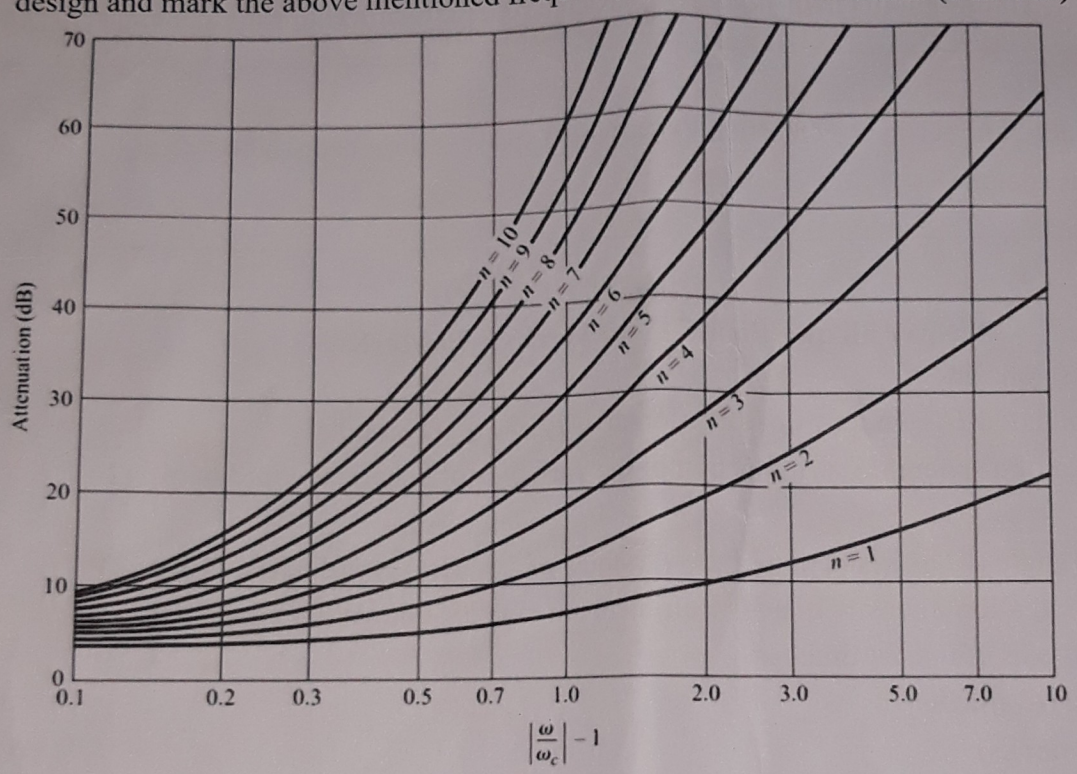

Figure 1. Attenuation characteristics of stepped imepdace low-pass filter having a maximally flat response

TABLE 8.3 Element Values for Maximally Flat Low-Pass Filter Prototypes ($g_0 = 1$, $\omega_c = 1$, $N = 1$ to 10)

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	2.0000	1.0000									
2	1.4142	1.4142	1.0000								
3	1.0000	2.0000	1.0000	1.0000							
4	0.7654	1.8478	1.8478	0.7654	1.0000						
5	0.6180	1.6180	2.0000	1.6180	0.6180	1.0000					
6	0.5176	1.4142	1.9318	1.9318	1.4142	0.5176	1.0000				
7	0.4450	1.2470	1.8019	2.0000	1.8019	1.2470	0.4450	1.0000			
8	0.3902	1.1111	1.6629	1.9615	1.9615	1.6629	1.1111	0.3902	1.0000		
9	0.3473	1.0000	1.5321	1.8794	2.0000	1.8794	1.5321	1.0000	0.3473	1.0000	
10	0.3129	0.9080	1.4142	1.7820	1.9754	1.9754	1.7820	1.4142	0.9080	0.3129	1.0000

06. a) Draw and briefly describe the construction of 3-dB equal split Wilkinson power divider. (5 marks) [10]

b) Draw the transmission line equivalent of the 3dB equal split Wilkinson power divider. (2 marks)

c) Write the scattering matrix of the Wilkinson power divider and comment on the respective values of the S matrix. (3 marks)

07. (a) A GaAs FET has the following S parameters at 5 GHz with $V_{ds} = 3.6$ V and $I_{ds} = 30$ mA and the reference impedance $Z_0 = 40\ \Omega$. [10]

$S_{11} = 0.85\angle -60°$

$S_{21} = 3\angle 120°$

$S_{12} = 0.01\angle 50°$

$S_{22} = 0.75\angle -30°$

i) Find the Delta factor (2 marks)

ii) Find the Stability factor. (3 marks)

iii) Is the system stable? Provide reason for the same. (2 marks)

(b) The S-parameters of a transistor at 4 GHz for a conjugate matched transistor amplifier are given by $S_{11} = 0.85\angle -100°$, $S_{21} = 2.3\angle 85°$, $S_{12} = 0$, $S_{22} = 0.75\angle 35°$. Find the maximum gain of the conjugate matched transistor amplifier. (3 marks)

Section - II

Answer all questions (2 X 15 Marks = 30 Marks)

08. (a) Briefly discuss the construction of the following two antennas and mention their applications (8 marks) [15]

i) Yagi-Uda antenna

ii) Parabolic reflector antenna

(b) A pyramidal horn antenna has E plane aperture a_E=10λ. The horn is fed by rectangular waveguide with TE_{10} mode. Let δ=0.22λ in E plane and 0.39λ in H plane. Determine

i) the length L along the axis, (2 marks)

ii) H Plane aperture (1 mark)

iii) flare angles in E plane (in degrees) (2 marks)

iv) flare angle in H plane (in degrees) (2 marks)

09. (a) A 6-dB branch line coupler as shown in Figure 2 given below has a directivity of 40 dB. If the input power P_1= 10 mW, [15]

i) Assume that the coupler is lossless, what are the powers outputs at ports 2, 3 and 4? (4 marks)

ii) Assume that the coupler has an insertion of 0.5 dB, what are the powers outputs at ports 2, 3 and 4? (3 marks)

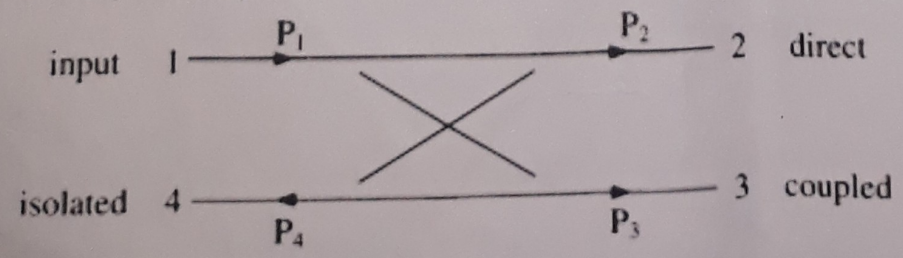

Figure 2. Branch line coupler

(b) The S matrix of a two port network is given below:

$$[S] = \begin{bmatrix} 0.3\angle 0^\circ & 0.5\angle 90^\circ \\ 0.5\angle 90^\circ & 0.1\angle 0^\circ \end{bmatrix}$$

i) Is the network reciprocal? Give proof using Unitary property. **(3 marks)**

ii) Is the network lossless? Give proof. **(2 marks)**

iii) Find return loss at port 1 when port 2 is short circuited. **(3 marks)**

Formula

$D_0 = \frac{U_{max}}{U_0}$

$G_0 = e_{cd} D_0$

$G_{re} = e_r G_0$

$e_r = (1 - |\Gamma|^2)$

$U_0 = \frac{P_{rad}}{4\pi}$

$P_{rad} = e_t \, P_{input}$

$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi R}\right)^2 G_{ot} G_{or}$

$e_{cd} = e_c e_d$

$\frac{P_r}{P_t} = e_{cdt} e_{cdr} (1 - |\Gamma_t|^2)(1 - |\Gamma_r|^2) \sigma \frac{D_t D_r}{4\pi} \left(\frac{\lambda}{4\pi R_1 R_2}\right)^2 |\hat{\rho}_w \bullet \hat{\rho}_r|^2$

$D_0 = \frac{4\pi}{\Omega_A} \approx \frac{4\pi}{\Theta_{1r}\Theta_{2r}}$

$AF = \frac{\sin(N\psi/2)}{\sin(\psi/2}$

$\psi = kdcos\theta + \beta$

Nulls of Uniform array: $\theta_n = \cos^{-1}[\frac{\lambda}{2\pi d}(-\beta \pm \frac{2n\pi}{N})]$

$\theta_h = \cos^{-1}[\cos\theta_0 - 0.443\frac{\lambda}{L+d}] - \cos^{-1}[\cos\theta_0 + 0.443\frac{\lambda}{L+d}]$

$\Gamma_1 = S_{11} + \frac{S_{12}^2 \Gamma_2}{1 - S_{22}\Gamma_2}$

$\tau = L_{n+1}/L_n = S_{n+1}/S_n = d_{n+1}/d_n$

$\sigma = \frac{S_n}{2L_n}$

$\alpha = \tan^{-1}(\frac{L_n - L_{n+1}}{2s_n})$

$L = \frac{a^2}{8\delta}$

$\cos(\theta/2) = \frac{L}{L+\delta}$

$\sin(\theta/2) = \frac{a/2}{L+\delta}$

$\tan(\theta/2) = \frac{a/2}{L}$

$D = 10\log\frac{7.5A_p}{\lambda^2}$

$\Gamma_L = \frac{Z_{Lout} - Z_{out}^*}{Z_{Lout} + Z_{out}^*}$

$\Gamma_s = \frac{Z_{sin} - Z_{in}^*}{Z_{sin} + Z_{in}^*}$

$\Gamma_{out} = S_{22} + \frac{S_{12}S_{21}\Gamma_s}{1 - S_{11}\Gamma_s}$

$\Gamma_{in} = S_{11} + \frac{S_{12}S_{21}\Gamma_L}{1 - S_{11}\Gamma_L}$

$G = \frac{|S_{21}|^2(1 - |\Gamma_L|^2)}{(1 - |\Gamma_{in}|^2)(1 - |S_{22}\Gamma_L|^2)}$

$G_A = \frac{|S_{21}|^2(1 - |\Gamma_s|^2)}{(1 - |S_{11}\Gamma_s|^2)(1 - |\Gamma_{out}|^2)}$

$G_T = \frac{|S_{21}|^2(1 - |\Gamma_s|^2)(1 - |\Gamma_{in}|^2)}{(1 - |\Gamma_s\Gamma_{in}|^2)(1 - |S_{22}\Gamma_L|^2)}$

$G_{TUmax} = \frac{|S_{21}|^2}{(1 - |S_{11}|^2)(1 - |S_{22}|^2)}$

$|\Delta| = S_{11}S_{22} - S_{12}S_{21}$

$K = \frac{1 + |\Delta|^2 - |S_{11}|^2 - |S_{22}|^2}{2|S_{12}S_{21}|^2}$