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2006

ELECTRONICS

SECOND PAPER

Full Marks : 200

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Given $v(t) = u_{-1}(t)e^{-\alpha t}$.

(a) What is its Fourier transform?

(b) What is its autocorrelation function?

(c) Calculate the energy density spectrum. 15

2. The electric field density as given as $\vec{E} = 120\pi\cos(10^9 t - 5z)\hat{a}_x \text{V/m}$ represents a uniform plane wave propagating in a lossless medium ($\varepsilon = \varepsilon_0\varepsilon_r = 4$, $\mu = \mu_0$, $\sigma = 0$) in the $+z$ direction. Determine—

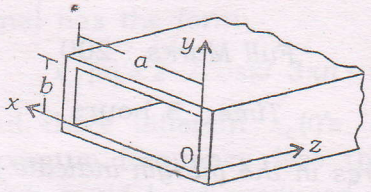
(a) the dielectric constant of the medium;

(b) the velocity of the wave propagation;

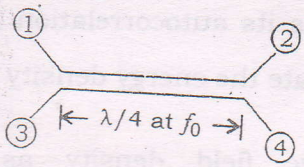
(c) the wavelength;

(d) the average power density of the wave. 20

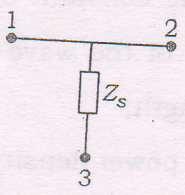
3. *(a)* As shown in figure, an air-filled waveguide operates at a frequency of 10 GHz. If the dimensions of the waveguide are $a = 2$ cm and $b = 1$ cm, determine the mode of propagation in the waveguide. 10



(b) Write the scattering matrix of a −10 dB coupled-line coupler shown below. Clearly indicate the isolated and coupled ports. 10



4. Calculate the S-matrix for the following network in terms of Z_s and Z_o. Write a 3×3 matrix. Check that it is lossless when $Z_s = 0$ and orthogonal when $Z_s = j\omega L$. 10+5+5



(Continued)

5. A center-fed, short dipole antenna of length $0{\cdot}1\lambda$ has a current of 0·707 A (r.m.s.) at its terminals. If the operating frequency is 300 Mrad/s and the medium is free space, what are the field intensities at a distance of 3 km in a direction that is 30° from the dipole axis? 20

6. *(a)* A receiver is made up of three main elements a pre-amplifier, a mixer and an IF amplifier with noise figures 3 dB, 6 dB and 10 dB respectively. If the overall gain of the receiver is to be 30 dB, and the IF amplifier gain is 10 dB, determine the minimum gain of the pre-amplifier to achieve an overall noise figure of no more than 5 dB. The gain of the pre-amplifier is set to this minimum and the noise figure of the IF amplifier is increased to 20 dB. What is the system noise figure now? 10

(b) The speech quality for a mobile communication system is just acceptable, when the received power at the terminals of the mobile receiver is −105 dBm. Find the maximum acceptable propagation loss for the system when the transmit power at the base station is 40 W, base station feeder losses are 8 dB, base station antenna gain is 5 dB. Antenna gain of the mobile is 0 dB and feeder losses at the mobile are 2 dB. 10

7. Consider a satellite link between an earth station (located at 61°28′45″ N latitude, 23°47′30″ E longitude) and a geostationary satellite whose satellite subpoint is at 0° latitude 0° longitude. The transmitting frequency is 5·5 GHz. How far a transmitting beam goes in a rain area? Determine the—

(a) elevation angle;

(b) distance;

(c) free space loss. 15

8. (a) A mobile phone is moving in a city environment. The received signal suffers Rayleigh multipath fading. What is the minimum required fade margin (in dB) to make the channel available with 95% probability? 10

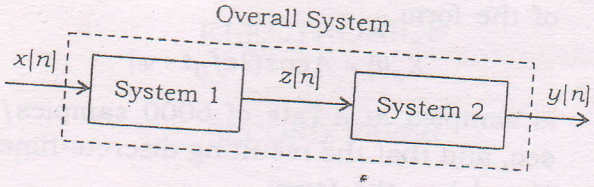
(b) A Rayleigh fading radio channel has a delay spread of $T_m = 1$ ms and Doppler spread $B_d = 10$ Hz. The signaling bandwidth is 25 kHz.

(i) Estimate the coherence bandwidth and the coherence time of the channel.

(ii) Is this a frequency selective channel?

(iii) Are we dealing with a slowly varying channel? 15

9.



Consider the discrete-time system above characterized by the following two input-output relationships :

System 1 : $z[n] = x[n-1] + x[n] + x[n+1]$

System 2 : $y[n] = z[n-1] + z[n] + z[n+1]$

(a) Is the overall system linear? Substantiate your answer.

(b) Is the overall system time-invariant? Substantiate your answer.

(c) Determine and plot the impulse response of this system.

(d) Is this system causal? Substantiate your answer.

(e) Is this system stable? Substantiate your answer.

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10. (a) Suppose the impulse response of an LTI system is $h(n) = 2 - nu(n)$. Find its responses to the following input signal : 10

$$x(n) = 2nu(-n)$$

(b) Suppose that a continuous-time signal of the form

$$X_c(t) = A\cos(2\pi f_0 t + \varphi)$$

is sampled at a rate of 6000 samples/sec, and that the resulting discrete-time signal has the form

$$x_d[n] = 2 \cdot 2\cos(0 \cdot 3\pi n - \pi/3)$$

Find three different $x_c(t)$'s, all with a maximum frequency less than 8 kHz, which could have produced $x_d[n]$. 10

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