CLASS TEST

Sl. : 02 SKEC_EFGHIJK_021023

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COMMUNICATIONS

ELECTRONICS ENGINEERING

Date of Test : 02/10/2023

ANSWER KEY

1.	(c)	7.	(b)	13.	(c)	19.	(a)	25.	(b)
2.	(a)	8.	(a)	14.	(d)	20.	(b)	26.	(c)
3.	(a)	9.	(d)	15.	(c)	21.	(c)	27.	(b)
4.	(a)	10.	(c)	16.	(a)	22.	(b)	28.	(b)
5.	(c)	11.	(b)	17.	(c)	23.	(a)	29.	(a)
6.	(a)	12.	(a)	18.	(b)	24.	(a)	30.	(c)

Detailed Explanations

1. (c)

The condition required to eliminate the slope-overload distortion is,

$$\frac{\Delta}{T_s} \geq \left|\frac{dm(t)}{dt}\right|_{\max} = |2\pi f_m \sin(2\pi f_m t)|_{\max}$$

$$2f_s \geq 2\pi f_m$$

$$f_s \geq \pi f_m \approx 3.14 f_m$$

$$f_{s(\min)} = 3.14 f_m$$

2. (a)

$$\text{Quality factor, } Q = \frac{f_c}{B}$$

$$\text{Range of } Q,\ 10 < Q < 100$$

$$10 < \frac{f_c}{B} < 100$$

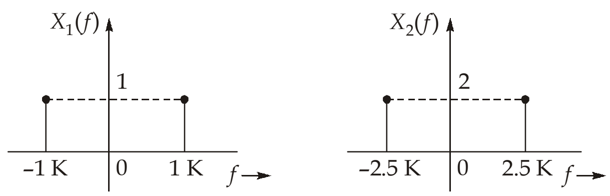
$$\frac{f_c}{B} > 10 \qquad \frac{B}{f_c} < 0.1$$

$$\frac{f_c}{B} < 100 \qquad \frac{B}{f_c} > 0.01$$

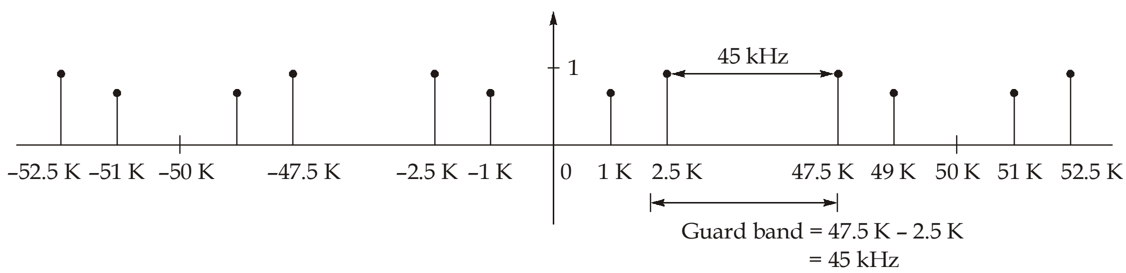
$$0.01 < \frac{B}{f_c} < 0.1$$

3. (a)

Before sampling



After sampling at a frequency of f_s = 50 kHz, $X_s(f)_{n=-\infty}^{\infty} = \Sigma X_1(f - nf_s)_{n=-\infty}^{\infty} + \Sigma X_2(f - nf_s)$



4. (a)

Autocorrelation function has maximum value at $\tau = 0$.

$\therefore$ $$R_{XX}(0) \geq R_{XX}(\tau)$$

Autocorrelation function is even function.

$\therefore \quad R_{XX}(-\tau) = R_{XX}(\tau)$

Value of autocorrelation function decreases as τ increases.

5. (c)

$$\text{Bit duration, } T_b = \frac{1}{R_b}$$

$$R_b = nf_s$$

$$f_s = 5 \times 2 \times 2 = 20 \text{ kHz}$$

$$T_b = \frac{1}{n \times 20 \times 10^3}$$

$$5 \times 10^{-6} = \frac{1}{n \times 20 \times 10^3}$$

$$n = \frac{10^3}{20 \times 5}$$

$$n = 10$$

6. (a)

$$P(x_1\, x_2\, x_1\, x_3) = (0.4)(0.3)(0.4)(0.2) = 0.0096$$

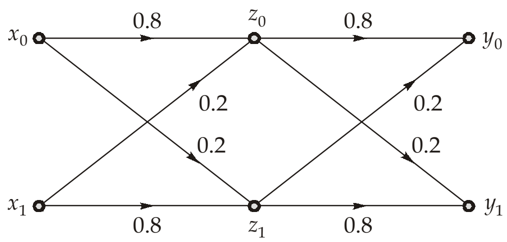
$$\therefore \quad \text{Information, } I(x_1\, x_2\, x_1\, x_3) = -\log_2(0.0096) = 6.7 \text{ bits}$$

$$P(x_4\, x_3\, x_3\, x_2) = (0.1)(0.2)(0.2)(0.3) = 0.0012$$

$$\text{I}(x_4\, x_3\, x_3\, x_2) = -\log_2(0.0012) = 9.7 \text{ bits}$$

$$\therefore \quad \text{Ratio} = \frac{6.7}{9.7} = 0.691$$

7. (b)



Crossover probability of overall channel = $P(y_0|x_1) = P(y_1|x_0)$

$$P(y_0|x_1) = P(y_0|z_0)\, P(z_0|x_1) + P(y_0|z_1)\, P(z_1|x_1)$$

$$= (0.80 \times 0.20) + (0.20 \times 0.80) = 0.32$$

So, the crossover probability of the resultant BSC = 0.32

8. (a)

$$H(x) = -\sum_{i=0}^{3} P(x_i)\log_2 P[x_i]$$

$$= -\left[\frac{1}{2}\log_2\left(\frac{1}{2}\right) + \frac{1}{4}\log_2\left(\frac{1}{4}\right) + \frac{1}{8} \times 2\log_2\left(\frac{1}{8}\right)\right]$$

$$= \frac{1}{2} + \frac{2}{4} + \frac{6}{8}$$

$$H(x) = 1.75 \text{ bits/symbol}$$

9. (d)

For matched filter,

$$(\text{SNR})_{max} = \frac{2E_s}{N_0}$$

$$E_s = \text{Energy of the signal } s(t)$$

$$= \int_{-\infty}^{\infty} |s(t)|^2 dt = \int_0^2 (4)^2 dt = 32$$

So, $$(\text{SNR})_{max} = \frac{2(32)}{N_0} = \frac{64}{N_0}$$

10. (c)

For coherent BPSK,

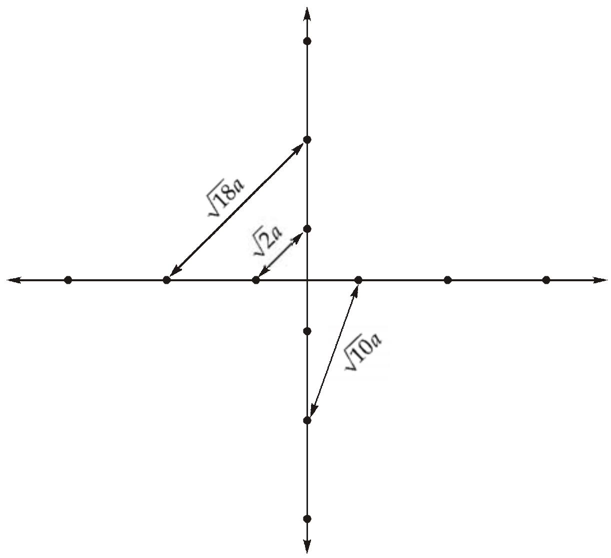
$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{E_b}{(N_0/2)}}\right)$$

$$= Q\left(\sqrt{\frac{10 \times 10^{-6}}{1 \times 10^{-9}}}\right) = Q\left(\sqrt{10^4}\right) = Q(100)$$

11. (b)

Probability of error in terms of Q-function is given by,

$$P_e = Q\left(\sqrt{\frac{d_{min}^2}{2N_0}}\right)$$



$$d_{min} = \sqrt{2}a = 2\sqrt{2}$$

$$\frac{N_0}{2} = 4 \text{ W/Hz}$$

$$N_0 = 8 \text{ W/Hz}$$

$$P_e = Q\left(\sqrt{\frac{d_{\min}^2}{2N_0}}\right) = Q\left(\sqrt{\frac{(2\sqrt{2})^2}{2\times 8}}\right)$$

$$P_e = Q\left(\sqrt{\frac{8}{2\times 8}}\right)$$

$$P_e = Q(\sqrt{0.5})$$

12. (a)

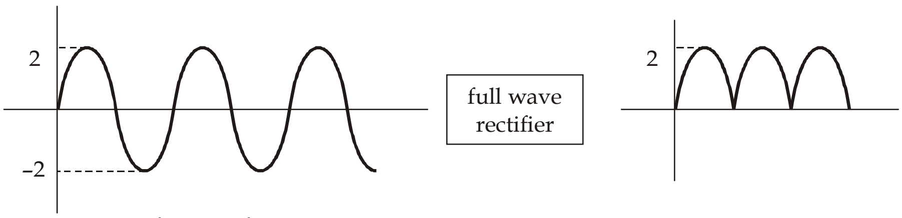
$$p(0/1) = 0.25$$
$$p(0/1) = 1 - q$$
$$1 - q = 0.25$$
$$q = 0.75$$

$$p(z = 0) = 0.4 = p(0)p\left(\frac{0}{0}\right) + p(1)p\left(\frac{0}{1}\right)$$

$$0.4 = 0.5p + 0.5 \times 0.25$$
$$0.4 = 0.5p + 0.125$$
$$0.5p = 0.275; \quad p = 0.55$$

Crossover probabilities → $(1 - p) = 0.45$ and $(1 - q) = 0.25$

13. (c)



Before rectification

RMS value of signal remains same after rectification but dynamic range decreases therefore step size decreases and Noise power decreases.

$$\text{Signal power} = \frac{A^2}{2} = \frac{2^2}{2} = 2$$

$$\text{Quantization Noise Power} = \frac{\Delta^2}{12} \text{ where } \Delta = \text{step size}$$

$$\Delta = \frac{2-0}{2^n} = \frac{2}{2^8} = \frac{1}{2^7}$$

$$\frac{S}{N} = \frac{2}{1}\cdot 2^{14} \times 12 = 393216 = 55.94 \text{ dB}$$

14. (d)

$$Z = 2X + Y$$
$$E[Z] = E[2X + Y]$$
$$= 2E[X] + E[Y]$$
$$E[X] = 0, \quad E[Y] = 0$$

Therefore, $E[Z] = 0$

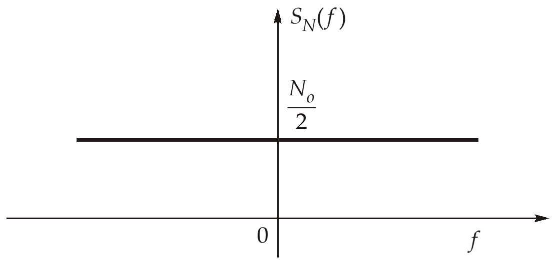
$$\text{Var}(Z) = E[Z^2] - E[Z]^2$$
$$= E[(2X+Y)^2] - 0$$
$$= E[4X^2 + Y^2 + 4XY]$$
$$= 4E[X^2] + E[Y^2] + 4E[XY]$$
$$E[X^2] = \text{Var}[X] \text{ as } E[X] = 0$$
$$E[Y^2] = \text{Var}[Y] \text{ as } E[Y] = 0$$
$$E[XY] = E[X]\,E[Y] \text{ as } X \text{ and } Y \text{ are independent}$$

Therefore, $\text{Var}(Z) = 4 \times 1 + 1 + 4 \times 0$

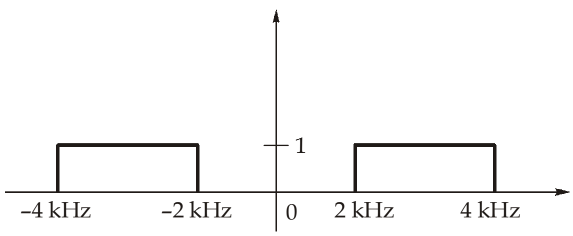
$$\text{Var}(Z) = 5$$

15. (c)

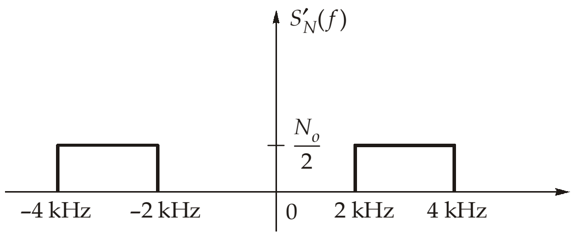
Power spectral density of white noise



Frequency response of filter



Noise after passing through the filter



Output noise power = Area under power spectral density curve

$$= 2 \times \frac{N_o}{2} \times 2 \times 10^3 = 2 \times 4 \times 10^{-6} \times 10^3$$
$$= 8 \times 10^{-3} \text{ W} = 8 \text{ mW}$$

16. (a)

Local oscillation frequency, $f_{LO} = f_s + f_{IF}$

$$\text{Maximum } f_{LO} = f_{s_{max}} + f_{IF}$$

$$f_{LO_{max}} = 1600 + 455 = 2055 \text{ kHz}$$

Minimum local oscillation frequency, $f_{LO_{min}} = f_{s_{min}} + f_{IF}$

$$f_{LO_{min}} = 540 + 455 = 995 \text{ kHz}$$

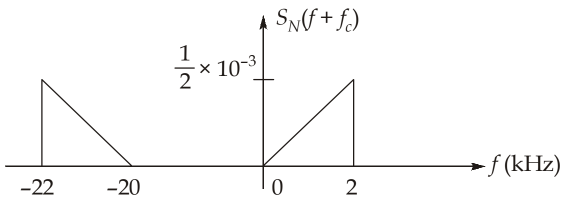
$$\frac{f_{LO_{max}}}{f_{LO_{min}}} = \frac{2055}{995} = 2.065$$

17. (c)

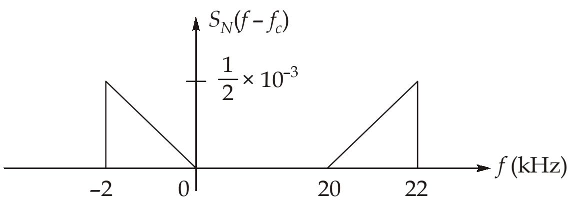
$$S_{N_C}(f) = \begin{cases} S_N(f - f_c) + S_N(f + f_c), & -B \le f \le B \\ 0 & \text{else} \end{cases}$$

$$f_c = 10 \text{ kHz},$$

Plotting $S_N(f + f_c)$



Plotting $S_N(f - f_c)$



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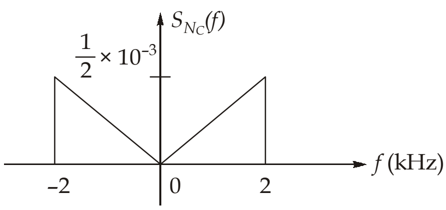


18. (b)

If X is equally likely to take both positive and negative values then,

$$P(X < 0) = P(X > 0)$$

$$P(X) = \text{Area under curve}$$

$$P(X < 0) = b \times 1 = b$$

$$P(X > 0) = b^2 \times 4 = 4b^2$$

$$b = 4b^2$$

$$b = \frac{1}{4}$$

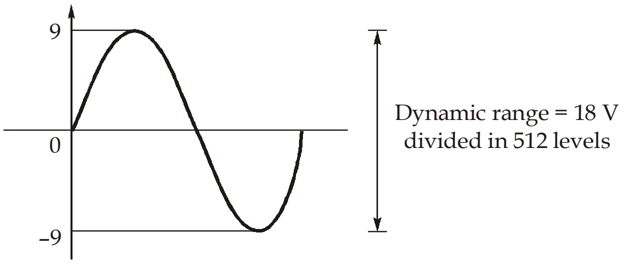
Also, Area of PDF curve = 1

$$b + 4b^2 + a = 1$$

$$\frac{1}{4} + 4 \times \frac{1}{16} + a = 1$$

$$a = 1 - \frac{1}{2} = 0.5$$

19. (a)



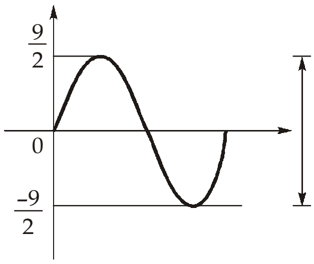
Now output of resistive network = $\frac{1}{2}V_i = \frac{9}{2}\sin\omega_m t$

Dynamic range = 9 V

Dynamic ranges reduces to $\frac{1}{2}$

Step size remains same,

$\therefore$ No. of levels $\frac{1}{2} \times 512 = 256$



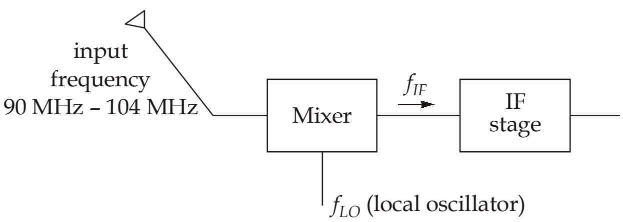
As Dynamic range reduces, $n = 8$

$$\frac{S}{N} = 1.76 + 6n$$

$$= 1.76 + 6 \times 8$$

$$= 49.8 \text{ dB}$$

20. (b)



$$f_{LO} = f_s + f_{IF}$$

$$f_{si} \text{ (image frequency)} = f_s + 2f_{IF}$$

When $f_s = 90$ MHz

$$f_{LO} = f_s + f_{IF}, f_{si} = f_s + 2f_{IF}$$

We have to select f_{IF} such that f_{si} falls outside the tuned range.

$$f_{si} \geq 104 \text{ MHz}$$

$$104 = 90 + 2f_{IF}$$

$$f_{IF_{\min}} = 7 \text{ MHz}$$

21. (c)

Probability of transmitting zero, $P(0) = \frac{2}{3}$

Probability of transmitting one, $P(1) = 1 - \frac{2}{3} = \frac{1}{3}$

$$P\text{ (at least two bits are zeroes)} = 1 - P(\text{no bit is zero}) - P\text{ (one bit is zero)}.$$

$$= 1 - {}^5C_0\left(\frac{2}{3}\right)^0\left(\frac{1}{3}\right)^5 - {}^5C_1\left(\frac{2}{3}\right)^1\left(\frac{1}{3}\right)^4$$

$$= 1 - \frac{1}{3^5} - \frac{10}{3^5}$$

$$= 1 - \frac{11}{243} = 0.954$$

22. (b)

The angle of the modulated signal $s(t)$ can be given as,

$$\theta(t) = 2\pi f_c t + 4\sin(4000\pi t) + 3\cos(4000\pi t)$$

The instantaneous frequency of the modulated signal can be given as,

$$f_i = \frac{1}{2\pi}\frac{d[\theta(t)]}{dt}$$

$$f_i = f_c + \frac{1}{2\pi}[4 \times 4000\pi\cos 4000\pi t + 3 \times 4000\pi[-\sin 4000\pi t]]$$

$$= f_c + [8000\cos(4000\pi t) - 6000\sin(4000\pi t)]$$

$$= f_c + 2000 \times 5[\cos(4000\pi t + \alpha)] \text{ where } \alpha = \tan^{-1}\left(\frac{3}{4}\right)$$

$$f_{i(\max)} = f_c + 2000 \times 5$$

$$= 100\text{ kHz} + 10\text{ kHz}$$

$$f_{i(\max)} = 110\text{ kHz}$$

23. (a)

The carrier component of the FM signal will be zero when $J_0(\beta) = 0$.

We know $J_0(\beta) = 0$ for $\beta = 2.41, 5.52, 8.65, 11.8$ ......

So, when $A_m = 4$ V, the corresponding modulation index is $\beta = 2.41$.

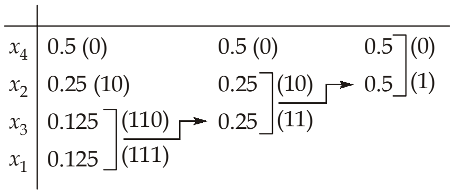
$$\beta = 2.41$$

$$\beta = \frac{\Delta f}{f_m} = \frac{k_f A_m}{f_m}$$

$$k_f = \frac{\beta f_m}{A_m} = \frac{2.41 \times 2 \times 10^3}{4}$$

$$k_f = 1.205\text{ kHz/V}$$

24. (a)



$$L = \sum_{i=1}^{4} P(x_i)n_i$$

$$= (0.5 \times 1) + (0.25 \times 2) + (0.125 \times 3) + (0.125 \times 3)$$

$$= 0.5 + 0.5 + 0.75$$

$$L = 1.75 \text{ bits/symbol}$$

$$H = -\sum_{i=1}^{4} P(x_i)\log_2 P(x_i)$$

$$H = -\left[\frac{1}{2}\log_2\left(\frac{1}{2}\right) + \frac{1}{4}\log_2\left(\frac{1}{4}\right) + \frac{2}{8}\log_2\left(\frac{1}{8}\right)\right]$$

$$H = 1.75 \text{ bits/symbol}$$

$$\eta = \frac{H}{L} = \frac{1.75}{1.75} = 1$$

Redundancy $\gamma = 1 - \eta = 1 - 1 = 0$

25. (b)

Bandwidth of the baseband signal with raised cosine pulse shaping will be,

$$(\text{BW})_{\text{signal}} = \frac{R_b}{2}(1+\alpha) = \frac{1000}{2}(1+\alpha) = 500(1+\alpha)\text{ kHz}$$

For proper transmission of the data,

$$(\text{BW})_{\text{signal}} \le (\text{BW})_{\text{channel}}$$

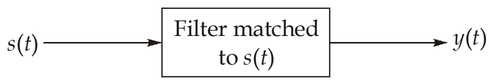
$$500(1 + \alpha) \le 600$$

$$(1 + \alpha) \le 1.20$$

$$\alpha \le 0.20$$

$$\alpha_{\text{max}} = 0.20$$

26. (c)



For a matched filter, peak value of the output will be numerically equal to the energy of the input signal.

So,
$$|y(t)|_{\text{max}} = \int_{-\infty}^{\infty} |s(t)|^2\, dt$$

$$s(t) = \begin{cases} \left(3 - \frac{3}{2}|t|\right)\text{V}; & 0 \le |t| \le 2 \\ 0 \quad ; & \text{otherwise} \end{cases}$$

So, $$|y(t)|_{max} = 2\int_0^2 \left(3-\frac{3}{2}t\right)^2 dt$$

$$= \frac{9}{2}\int_0^2 (t^2+4-4t)\,dt$$

$$= \frac{9}{2}\left[\frac{t^3}{3}+4t-2t^2\right]_0^2 = 12 \text{ V}$$

27. (b)

$$f_Z(z) = f_X(z) * f_Y(z)$$
$$f_X(z) = ae^{-az}\,u(z)$$
$$f_Y(z) = be^{-bz}\,u(z)$$

$$L\{f_X(z)\} = \frac{a}{s+a} \quad \text{and} \quad L\{f_Y(z)\} = \frac{b}{s+b}$$

$$f_Z(z) = L^{-1}\left\{\frac{ab}{(s+a)(s+b)}\right\} = L^{-1}\left\{\frac{ab}{(b-a)}\left[\frac{1}{(s+a)}-\frac{1}{(s+b)}\right]\right\}$$

$$= \frac{ab}{(b-a)}\left[e^{-az}-e^{-bz}\right]u(z)$$

28. (b)

The transmission efficiency of an AM signal can be given by,

$$\eta = \frac{k_a^2 P_m}{1+k_a^2 P_m}$$

Here, k_a = amplitude sensitivity of the modulator = 0.25 V^{-1}

P_m = Power of the message signal

For the given message signal,

$$P_m = A^2 = (2)^2 = 4$$

So, $$\eta = \frac{(0.25)^2(4)}{1+(0.25)^2(4)} = \frac{0.25}{1+0.25} = \frac{1}{5} = 0.20 \text{ (or) } 20\%$$

29. (a)

The rule to decide an optimum threshold value using MAP criteria is as follows:

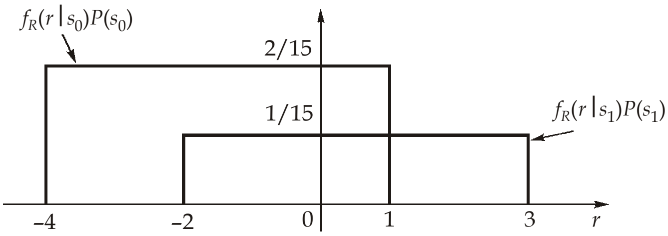
$$f_R(r\,|\,s_0)P(s_0) \underset{H_1}{\overset{H_0}{\gtrless}} f_R(r\,|\,s_1)P(s_1)$$

The above expression says that,

- Decision is made in favour of "0", if $f_R(r\,|\,s_0)P(s_0)$ is greater than $f_R(r\,|\,s_1)P(s_1)$.
- Decision is made in favour of "1", if $f_R(r\,|\,s_1)P(s_1)$ is greater than $f_R(r\,|\,s_0)P(s_0)$.

Given that $P(s_0) = \frac{2}{3}$ and $P(s_1) = \frac{1}{3}$.

The optimum threshold can be decided by using MAP criteria, by plotting the functions $f_R(r\,|\,s_1)P(s_0)$ and $f_R(r\,|\,s_1)P(s_1)$ as follows:



It is clear from the above diagram that,

For $r < 1$, $f_R(r\,|\,s_0)P(s_0) > f_R(r\,|\,s_1)P(s_1)$ and for $r > 1$, $f_R(r\,|\,s_1)P(s_1) > f_R(r\,|\,s_0)P(s_0)$.

So, the optimum threshold value is, $r_{th} = 1$.

30. (c)

The output of the narrowband FM modulator can be given by,

$$x(t) = A\cos[2\pi f_0 t + \phi(t)]\ ;\ |\phi(t)|_{max} = 0.10 \text{ radians}$$

The signal at the output of upper frequency multiplier can be given by,

$$y(t) = A\cos[2\pi n_1 f_0 t + n_1\phi(t)]$$

After mixing $y(t)$ with the output signal of the lower frequency multiplier, we get,

$$z(t) = A^2\cos[2\pi n_1 f_0 t + n_1\phi(t)]\cos[2\pi n_2 f_0 t]$$

$$= \frac{A^2}{2}\cos[2\pi(n_1+n_2)f_0 t + n_1\phi(t)] + \frac{A^2}{2}\cos[2\pi(n_1-n_2)f_0 t + n_1\phi(t)]$$

It is given that the mixer is designed for up-conversion. So, the signal $s(t)$ can be given by,

$$s(t) = \frac{A^2}{2}\cos[2\pi(n_1+n_2)f_0 t + n_1\phi(t)] \quad \text{...(i)}$$

It is given that, f_c = 104 MHz and Δf_{max} = 75 kHz for $s(t)$.

So, the modulation index of the wideband signal $s(t)$ will be,

$$\beta = \frac{\Delta f_{max}}{f_{m(max)}} = n_1|\phi(t)|_{max}$$

$$n_1(0.10) = \frac{75\text{ kHz}}{15\text{ kHz}} = 5$$

$$n_1 = \frac{5}{0.10} = 50$$

$$f_c = (n_1 + n_2)f_0 = 104 \text{ MHz}$$

$$(n_1 + n_2) \times 100 = 104 \times 1000$$

$$n_2 = 1040 - n_1 = 1040 - 50 = 990$$

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