Ministry of Higher Education & Scientific Research
University of Technology
Laser & Optoelectronic Eng. Department
Branch: Laser & Optoelectronics.
Class: Third Year
Subject: Communications & Wave Propagation

Final Examinations
Time: 3 Hours
Date: 24th May 2016
Examiner: Asst. L. Ahmed W.
Code: LOPE3202
Academic Year: 2015-2016

Attempt any FIVE questions

Q1: (A) [5 marks] Classify ***ONE*** of the following signals into energy-type, power-type, and neither energy-type nor power-type signals.

1- $x(t) = A\, e^{j(2\pi f t+\theta)}$
2- $y(t) = A\cos(2\pi f_1 t) + B\cos(2\pi f_2 t)$

(B) [7 marks] Determine and plot the Fourier transform of the rectangular function given by:

$$x(t) = \begin{cases} 1, & -T \le t \le T \\ 0, & elsewhere \end{cases}$$

Q2: (A) [6 marks] Suppose that the modulating signal $m_n(t)$ is a sinusoid of the form:

$$m_n(t) = \cos(2\pi f_m t)$$

Determine and plot the double-side band DSB signal, upper/lower sidebands, and the spectrum. Assume a modulation index of a.

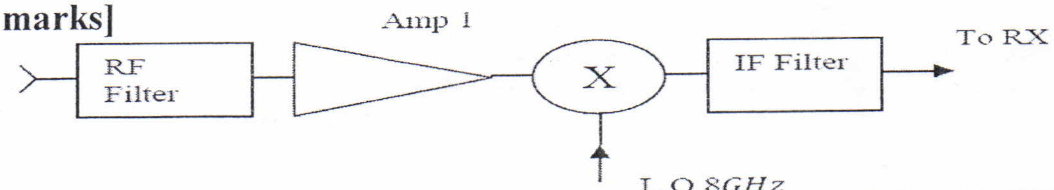
(B) [6 marks] Show cause for the following:

1- The message waveform in conventional AM (DSB-LC) is constrained to satisfy the condition that $|m(t)| \le 1$.
2- The transmission of either sidebands in single-sideband form is sufficient to reconstruct the message signal at the receiver.
3- The needs to tune RC value to satisfy the condition of $\frac{1}{f_c} \ll RC \ll \frac{1}{W}$, at the receiver through using of envelope detection method.

Q3: [12 marks] A 1-MHz carrier is frequency modulated by a 10-kHz sinusoid so that the peak frequency deviation is 30-kHz. Determine: ***(i)*** the approximate bandwidth of the FM, ***(iii)*** the bandwidth if the modulating signal frequency were dropped three times, and ***(ii)*** the sidebands of the FM spectrum. (Consider Bessel table values in your calculations and carrier voltage of 3 volts).

	0	**1**	**2**	**3**
$J_n(3)$	-0.2601	0.3391	0.4861	0.3091

Q4: [12 marks]



In the receiver shown in the diagram above, the RF band is 9.6 – 10 GHz, and the IF band is 1.6 – 2 GHz. The components parameters are as follows:

	RF Filter	Amp 1	Mixer	IF Filter	
Gain	-1	20	-6	-1	dB
Noise	1	?	7	1	dB
Input IP3	99	-10	6	99	dBm

Calculate; (1) The total gain of the receiver in decibels. (2) The output two-tone third order intercept point, (3) The amplifier noise figure in order to achieve a system noise figure of 2dB. **Where $k = 1.38 \times 10^{-23}$ J/K**

Q5: [12 marks] A microwave link is set up to communicate from a city to a nearby mountain top. The distance is 100 km, and the operating frequency is 10GHz. The receiver has a noise figure of 6dB, a bandwidth of 30MHz, and an operating temperature of 290K. Calculate (a) the received power in watts, (b) the received signal-to-noise power ratio in decibels at the receiver output port. (c) Repeat (b) if there is a thunderstorm that gives an additional loss of 5 dB/km for a region of 5km long between the transmitter and receiver. (Consider the table values in your calculations)

Transmitting power	10^3W	Atmospheric loss	-2dB
Transmitting Feed loss	-1.5dB	Polarization loss	-0.5dB
Transmitting antenna gain	45dB	Receiving feed loss	-1.5dB
T_X-R_X Antenna pointing error	-3dB	Receiving antenna gain	45dB

Q6: [12 marks] A microwave link operating at 10GHz with a path length of 30km has a maximum acceptable path loss of 169dB. The transmitter antenna is mounted at a height of 20m above ground level, while the height of the receiver antenna is to be determined. The ground is level apart from a hill of height 80m, located 10km away from the transmitter antenna. (a) Calculate the total path loss assuming the receiver antenna is mounted at a height of 20m above ground level. (b) Calculate the height of the receiver antenna for the path loss to be just equal to the maximum acceptable value.

Good luck

Q1. A) ① $E = \int_{-\infty}^{+\infty} |x(t)|^2 \, dt$

$= \int_{-\infty}^{+\infty} | A e^{j(2\pi f t + \theta)} dt|^2$

$= \int_{-\infty}^{+\infty} A^2 e^{2j(2\pi f t + \theta)} dt$

$= \int_{-\infty}^{+\infty} A^2 \, dt = \infty$ Not energy-type

$P = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{+T} |x(t)|^2 \, dt$

$= \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{+T} A^2 e^{2j(2\pi f t + \theta)} dt$

$= \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{+T} A^2 \, dt$

$= A^2$ it is apower-type signal

Q1 A) 2 Since $y(t)$ is periodic (or almost periodic when f_1/f_2 is rotational). Therefore, it is not energy-type signal.

To explore whether the function is power-type:

$$P = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} |x(t)|^2 \, dt$$

$$= \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{+T} | A\cos(2\pi f_1 t) + B\cos(2\pi f_2 t)|^2 \, dt$$

$$= \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} \Big[A^2 \cos^2(2\pi f_1 t) + B^2 \cos^2(2\pi f_2 t) + 2AB\cos(2\pi f_1 t)\cos(2\pi f_2 t) \Big]$$

$$= \frac{A^2 + B^2}{2}$$ It is power-type signal.

Q1 B)

$$x(t) = \begin{cases} 1 & -T \le t \le T \\ 0 & \text{elsewhere} \end{cases}$$

using the dif. of FT:-

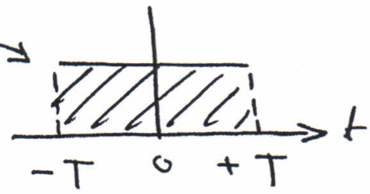
$$X(\omega) = \int_{-\infty}^{+\infty} x(t) e^{-j\omega t} \, dt$$

or

$$X(f) = \int_{-\infty}^{+\infty} x(t) e^{-j2\pi f t} \, dt$$

$$X(f)=\int_{-T}^{T} x(t)\, e^{-j2\pi f t}\, dt$$

rect. function $x(t)$



$$X(f)=\int_{-T}^{T} e^{-j2\pi f t}\, dt = \frac{1}{-j2\pi f}\, e^{-j2\pi f t}\Big|_{-T}^{+T}$$

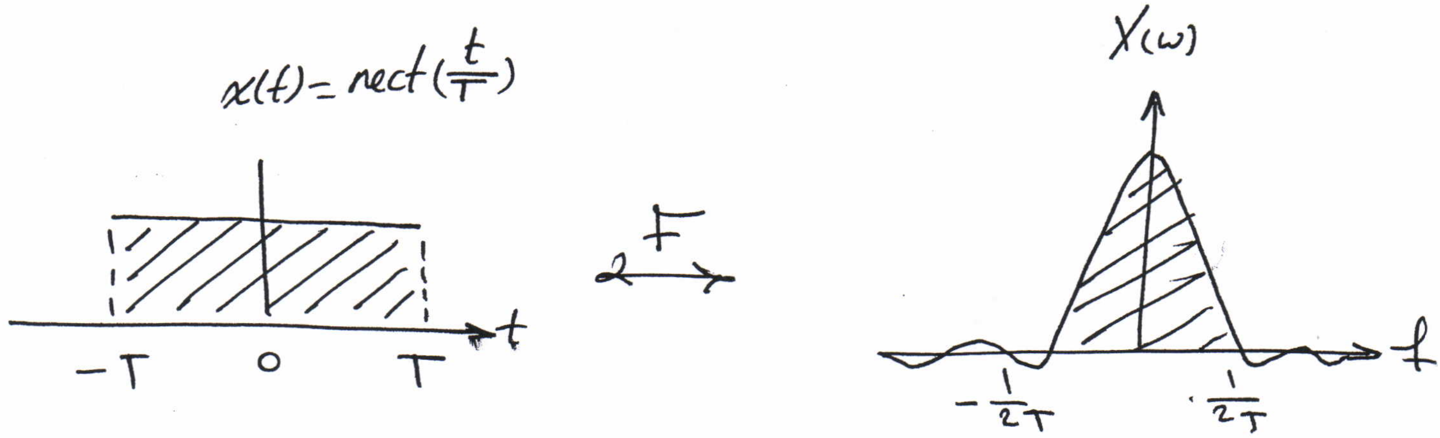
$$X(f)=\frac{2}{2\pi f}\,\sin(2\pi f T)$$

$$X(f)=2T.\ \frac{\sin\left(\pi\,\frac{2\pi f T}{\pi}\right)}{\left(\pi\,\frac{2\pi f T}{\pi}\right)}$$

$$X(f)=2T\ \mathrm{Sinc}\left(\frac{2\pi f T}{\pi}\right)$$

or

$$X(\omega)=2T\ \mathrm{Sinc}\left(\frac{\omega T}{\pi}\right)$$



Q2 A) $\quad m_n(t) = \cos(2\pi f_m t) \qquad f_m \ll f_c$

$$u(t) = A_c\left[1 + a\cos(2\pi f_m t)\right]\cos(2\pi f_c t)$$

$$= A_c\cos(2\pi f_c t) + \frac{A_c a}{2}\cos\left[2\pi(f_c - f_m)t\right] + \frac{A_c a}{2}\cos\left[2\pi(f_c + f_m\right.$$

<u>where</u> :-

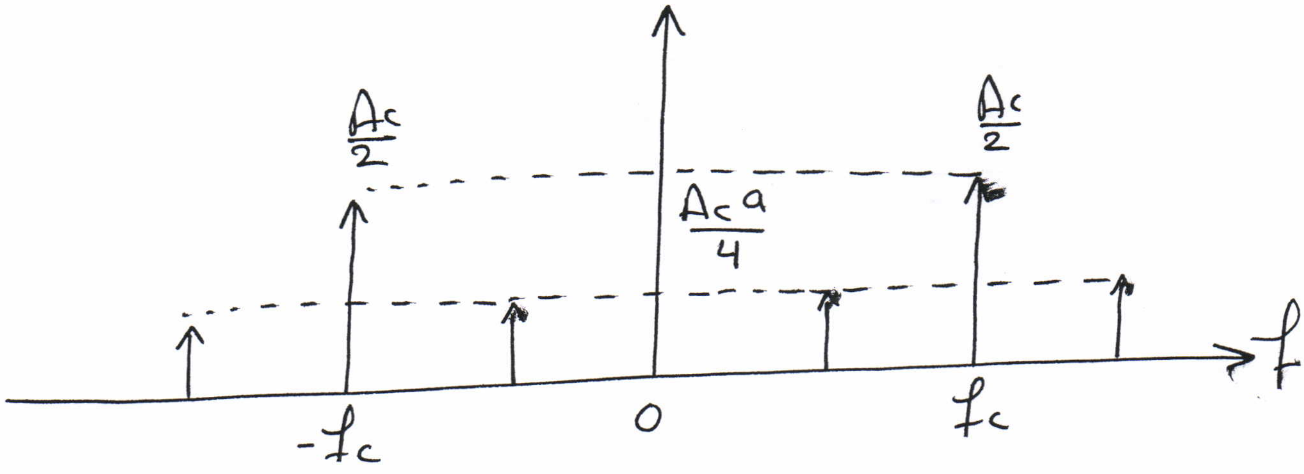
① $A_c\cos(2\pi f_c t) \equiv$ Large carrier component.

② $\frac{A_c a}{2}\cos\left[2\pi(f_c - f_m)t\right] \equiv$ Lower sideband component.

③ $\frac{A_c a}{2}\cos\left[2\pi(f_c + f_m)t\right] \equiv$ Upper sideband component.

The Spectrum :.

$$U(f) = \frac{A_c}{2}\left[\delta(f - f_c) + \delta(f + f_c)\right]$$
$$+ \frac{A_c a}{4}\left[\delta(f - f_c + f_m) + \delta(f + f_c - f_m)\right]$$
$$+ \frac{A_c a}{4}\left[\delta(f - f_c - f_m) + \delta(f + f_c + f_m)\right]$$



Q2. B)

1- Since the message signal satifies the condition $|m(t)|<1$ the envelope amplitude $1+m(t)>0$. Hence, as long as $m(t)\leq 1$, the amplitude $A_c[1+m(t)]$ is always positive. This is the desired condition for DSB-LC that makes it easy to demodulate, and there is no need for a synchronous demodulator. If we rectify the received signal, we eleminate the negative values without affecting the message signal

2- Because that the two sidebands contains a redundant information.

3- The time constant RC must be selected so as to follow the variation in the envelope of the carrier-modulated signal. In such case, the capacitor discharges slowly through the resister, and, thus, the output of the envelope detector closely follows the message signal.

Q3: (i)

$$\beta = \frac{\Delta f}{f_m} = \frac{30kHz}{10kHz} = 3 \rightarrow 20 > \beta > 1$$

$$B.W = 2(f_m + \Delta f) = 2(10\ kHz + 30\ kHz) = 80\ kHz$$

Q3: (ii)

$$f_m = \frac{10000}{3} = 3333.3 \rightarrow \beta = \frac{30000}{3333.3} = 9$$

$$B.W = 2\Delta f\left(1 + \frac{1}{\beta}\right) = 2 \times 30 \times 10^3 \times \left(1 + \frac{1}{9}\right) = 66.6\ kHz$$

Q3: (iii)

The FM spectrum can be found by using Bessel function of the given table at modulation index of 4, as follow (Note: The exponential for can also be used.):

$$x_c(t) = A_c\left\{\sum_{n=-\infty}^{+\infty} J_n(\beta)\exp[2\pi(f_c + nf_m)t]\right\}$$

At $n = 0$ and $J_0(3) = -0.2601$

We get only $f_c = 1\ MHz$ Amplitude $-0.26 \times 3 = -0.78\ volts$

At $n = \pm 1$ and $J_{\pm 1}(3) = 0.3391$

$(f_c + nf_m) = (1\ MHz + (1)10\ kHz) = 1010\ kHz$ Amplitude $1.02\ volts$

$(f_c - nf_m) = (1\ MHz - (1)10\ kHz) = 990\ kHz$ Amplitude $1.02\ volts$

At $n = \pm 2$ and $J_{\pm 2}(3) = 0.4861$

$(f_c + nf_m) = (1\ MHz + (2)10\ kHz) = 1020\ kHz$ Amplitude $= 1.46\ volts$

$(f_c - nf_m) = (1\ MHz - (2)10\ kHz) = 980\ kHz$ Amplitude $= 1.46\ volts$

At $n = \pm 3$ and $J_{\pm 3}(3) = 0.3091$

$(f_c + nf_m) = (1\ MHz + (3)10\ kHz) = 1030\ kHz$ Amplitude = 0.93 $volts$

$(f_c - nf_m) = (1\ MHz - (3)10\ kHz) = 970\ kHz$ Amplitude = 0.93 $volts$

Qu. 3)

$F_T = 2\ dB = 10^{0.2} = 1.585$ $\quad G_1 = 0.794$

$F_1 = 1\ dB = 10^{0.1} = 1.259$ $\quad G_2 = 100$

$F_2 = ?$ $\quad G_3 = 0.251$

$F_3 = 7\ dB = 10^{0.7} = 5.012$ $\quad G_4 = 0.794$

$F_4 = 1\ dB = 10^{0.1} = 1.259$

$$F_T = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3}$$

$$1.585 = 1.259 + \frac{F_2 - 1}{0.794} + \frac{5.012 - 1}{0.794 * 100} + \frac{1.259 - 1}{0.794 * 100 * 0.251}$$

$$1.585 = 1.259 + \frac{F_2 - 1}{0.794} + 0.051 + 0.013$$

$$1.585 = 1.323 + \frac{F_2 - 1}{0.794}$$

$$1.585 - 1.323 = \frac{F_2 - 1}{0.794}$$

$$0.262 = \frac{F_2 - 1}{0.794}$$

$$F_2 = (0.262 * 0.794) + 1$$

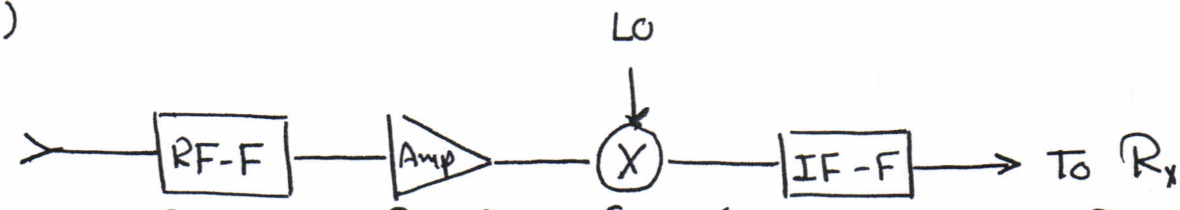
$$F_2 = 1.208 = 0.821\ dB$$

Q4 1) $G_T = G_1 + G_2 + G_3 + G_4$

$$= -1 + 20 - 6 - 1$$

$$= 12 \text{ dB}$$

2)



$G_1 = -1$ $\quad G_2 = 20$ $\quad G_3 = -6$ $\quad G_4 = -1$ $\quad$ dB

$iip3_1 = 99$ $\quad iip3_2 = -10$ $\quad iip3_3 = 6$ $\quad iip3_4 = 99$ $\quad$ dBm

$iip3_1 = 99_{dBm} = 10^{9.9}$ mW

$iip3_2 = -9_{dBm} = 0.126$ mW

$ip3_3 = -13$ dBm $= 0.05$ mW

$iip3_4 = 86$ dBm $= 10^{8.6}$ mW

$$IIP3_T = 10 \log \left(\frac{1}{iip3_1} + \frac{1}{iip3_2} + \frac{1}{iip3_3} + \frac{1}{iip3_4} \right)^{-1}$$

$$= 10 \log \left(\frac{1}{10^{9.9}} + \frac{1}{0.125} + \frac{1}{0.05} + \frac{1}{10^{8.6}} \right)^{-1}$$

$$= 10 \log (0.036 \text{ mW}) = -14.436 \text{ dBm}$$

$\therefore oip3_T = iip3_T + G_T = -14.436 \text{ dBm} + 12 \text{ dB}$

$$oip3_T = -2.437 \text{ dBm}$$

Q5: NOTE THAT THIS TYPE OF QUESTIONS HAVE DIFFERENT POSSIBLE WAY TO SOLVE THEM.

$$\lambda_0 = \frac{c}{f} = \frac{3 \times 10^8}{10 \times 10^9} = 0.03m$$

$$SL\ in\ dB = 20\log\left(\frac{4\pi R}{\lambda_0}\right) = 20\log\left(\frac{4 \times 3.14 \times 100 \times 10^3}{0.03}\right) = 152.4dB$$

The link budget is given by:

$$LB\ in\ dB = 10\log(1000W) + 45 - 1.5 - 1 - 152.4 - 2 - 0.5 + 45 - 1.5 - 2$$

$$LB\ in\ dB = -40.9dBW = -10.9dBm = 8.13 \times 10^{-5}W$$

Hence, the received power is $-40.9dBW = -10.9dBm = 8.13 \times 10^{-5}W$

The received carrier to noise ratio at the receiver output is:

$$\frac{S_o}{N_o}\ in\ dB = 10\log\left(\frac{P_r}{kTBF}\right) = 10logP_r - 10\log(kTBF)$$

$$F = 6dB = 3.98$$

$$\frac{S_o}{N_o}\ in\ dB = -40.9 - 10\log(1.38 \times 10^{-23} \times 290 \times 30 \times 10^6 \times 3.98)$$

$$\frac{S_o}{N_o}\ in\ dB = -40.9 - (-123.21) = 82.31dB$$

The total loss due to thunderstorm for all 5km is 25dB:

Hence, the link budget is completely altered as follow:

$$LB\ in\ dB = 10\log(1000W) + 45 - 1.5 - 1 - 152.4 - 2 - 0.5 - 25 + 45 - 1.5 - 2$$

$$LB\ in\ dB = -65.9dBW = -35.9dBm = 8.13 \times 10^{-7}W$$

The received signal to noise ratio at the receiver output is:

$$\frac{S_o}{N_o}\ in\ dB = 10\log\left(\frac{P_r}{kTBF}\right) = 10logP_r - 10\log(kTBF)$$

$$\frac{S_o}{N_o}\ in\ dB = -65.9 - 10\log(1.38 \times 10^{-23} \times 290 \times 30 \times 10^{6} \times 3.98)$$

$$\frac{S_o}{N_o}\ in\ dB = -65.9 - (-123.21) = 57.31dB$$

Q6:

(a) $L_{F_{dB}} = 32.4 + 20 \log R_{km} + 20 \log f_{MHz}$

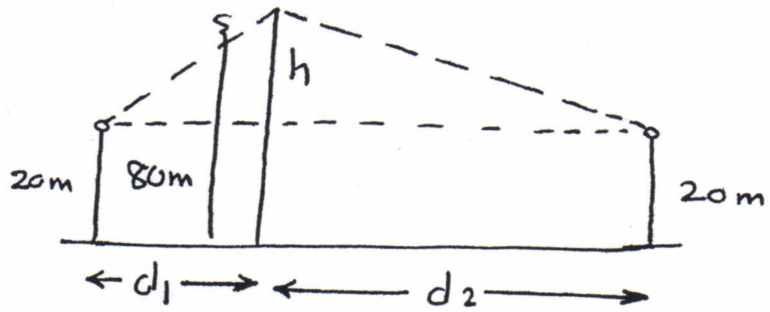
$$L_{F_{dB}} = 32.4 + 20 \log (30) + 20 \log (10\,000)$$

$$L_{F_{dB}} = 141.94 \text{ dB} \simeq 142 \text{ dB}$$

$d_1 = 10$ km

$d_2 = 20$ km

$d = 30$ km



$$\therefore h = 80\text{m} - 20\text{m} = 60\text{m}$$

$$\therefore \nu = h \left(\frac{2(d_1 + d_2)}{\lambda d_1 d_2} \right)^{\frac{1}{2}}$$

$$\nu = 60\text{m} \left(\frac{2 \times 30 \times 10^3}{3 \times 10^{-2} \times 10 \times 10^3 \times 20 \times 10^3} \right)^{\frac{1}{2}}$$

$$\nu = 6$$

The knife-edge loss is given by:

$$L_{ke} = -20 \log \left(\frac{0.225}{\nu} \right)$$

$$L_{ke} = -20 \log \left(\frac{0.225}{6} \right) = 28.5 \text{ dB}$$

The total path loss $= 142$ dB $+ 28.5$ dB

$= 170.5$ dB

- The total path loss is in excess of the maximum acceptable limit (169 dB) and so the system must be re designed.

(b) In order to reduce the obstruction loss to an acceptable level, the excess loss must be no longer than:

$$169 - 142 = 27\ dB = L_{ke}$$

$$\therefore \quad L_{ke} = -20 \log \frac{0.225}{\nu}$$

$$27\,dB = -20 \log \frac{0.225}{\nu}$$

$$10^{-27/20} = \frac{0.225}{\nu}$$

$$\nu = 5$$

$$\therefore \quad \nu = h\left(\frac{2(d_1+d_2)}{\lambda d_1 d_2}\right)^{\frac{1}{2}}$$

$$\cancel{h = \nu(\quad 2(d_1+d_2)}$$

$$h = \nu\left(\frac{\lambda d_1 d_2}{2(d_1+d_2)}\right)^{\frac{1}{2}}$$

$$h = 5\left(\frac{3\times10^{-2}\times 10\times10^{3}\times 20\times10^{3}}{2\times 30\times10^{3}}\right)^{\frac{1}{2}}$$

$$h = 5 \times 10 = 50\,m$$

The obstruction height is 80m as its given, however it must be of height of 50m. Hence, there are two ways either by reducing the hill height and that impossible or increasing h_r.

$$\therefore \quad h_r = 20 + (80m - 50m) = 50\,m$$