COMMUNICATION

Third stage

Electrical Power & Machines Engineering Department

College of Engineering

University of Diyala

Lecture 8

By

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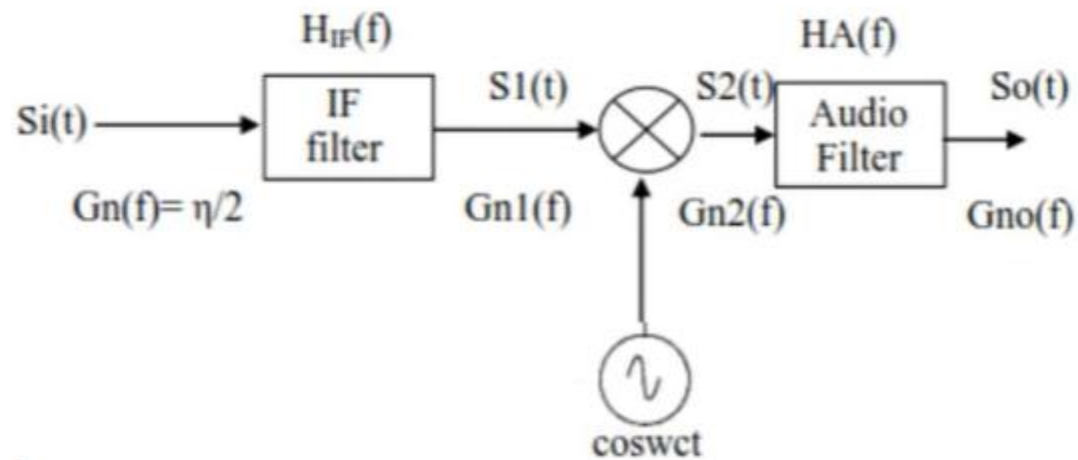
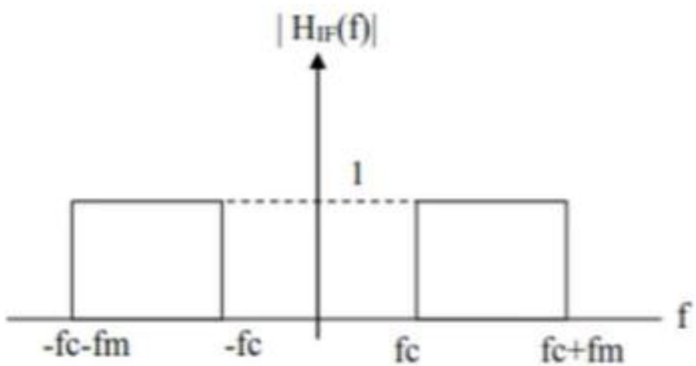
Noise in Amplitude and Frequency Modulation

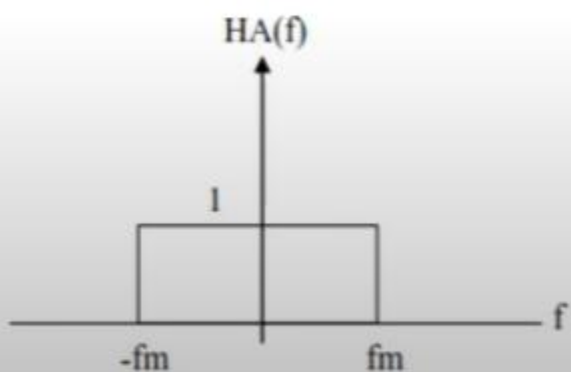
Noise in Amplitude Modulation

Noise in amplitude modulation systems:

1- Single sideband modulation:







fc= f_{IF} intermediate freq.

fm= base band bandwidth

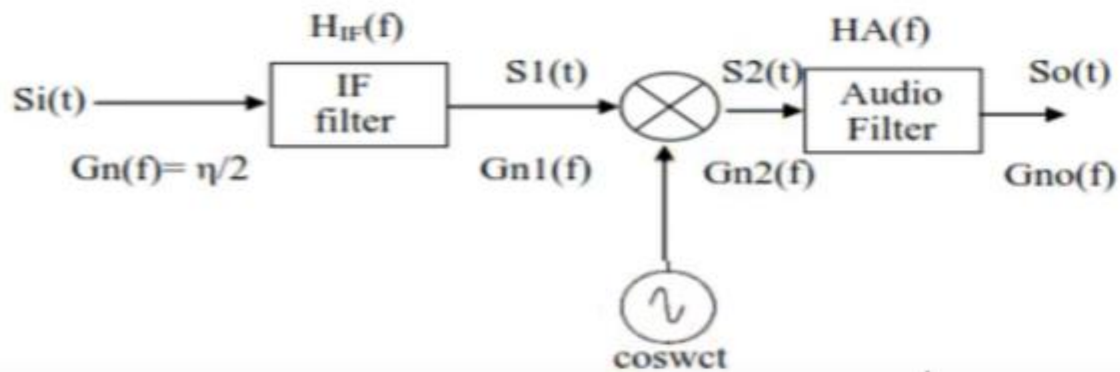
Noise in Amplitude Modulation

alculation of Signal Power:

- Assuming the received signal is SSB- USB
- The demodulator is a synchronous detector.

Let the modulating signal be a sinusoidal of freq. fm $(f(t) = \cos w_m t)$

$F_i(t) = A_c \cos(w_c + w_m)t$

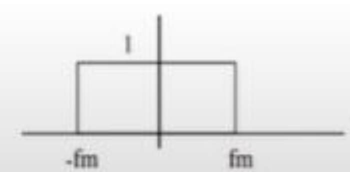


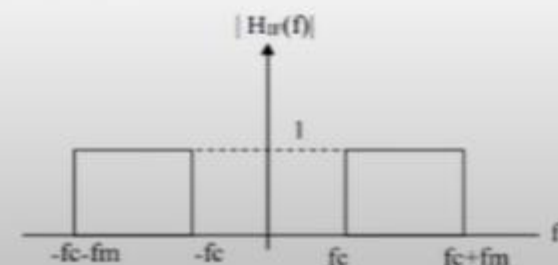
$F_1(t) = F_i(t)$

Multiplier o/p

$F_2(t) = F_1(t) \cos w_c t = A_c \cos(w_c + w_m)t \cos w_c t$

$= \frac{A}{2} \cos w_m t + \frac{A}{2} \cos(2w_c + w_m)t$





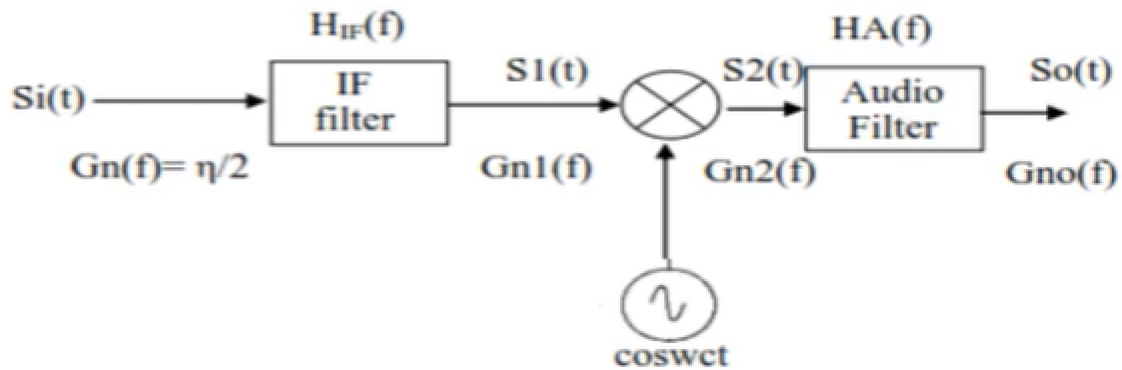
Noise in Amplitude Modulation

Output- signal $F_o(t) = \frac{A}{2}\cos w_m t$

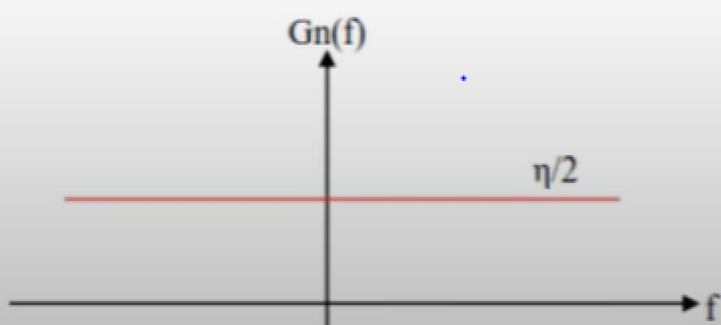
i/p signal power $S_i = \frac{A_c^2}{2}$

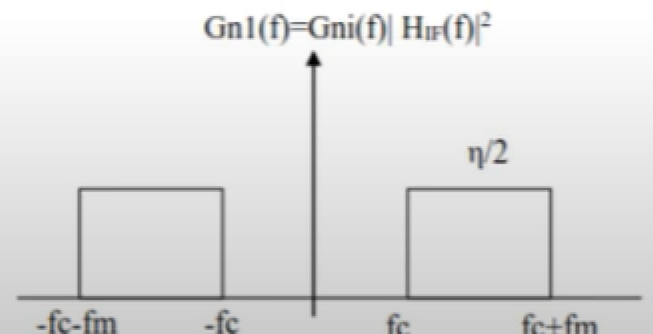
o/p signal power $S_o = \frac{A_c^2}{8}$

$\frac{S_o}{S_i} = \frac{1}{4}$



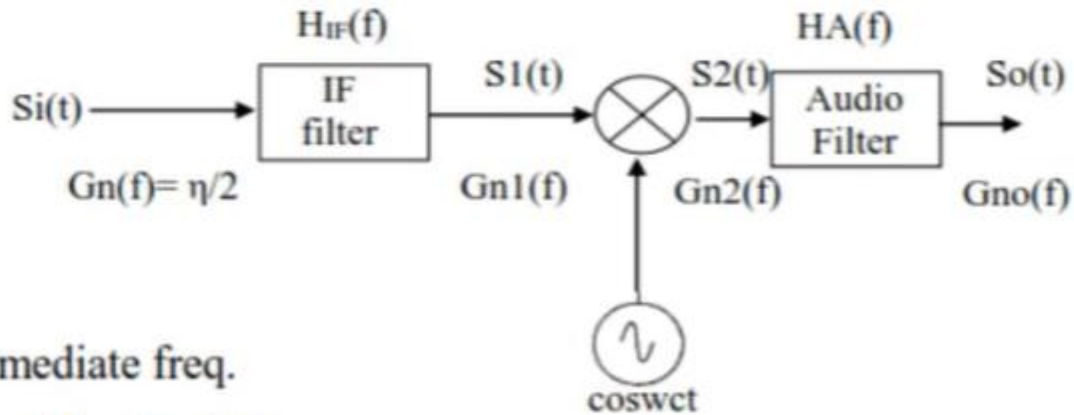
Calculation of noise power:





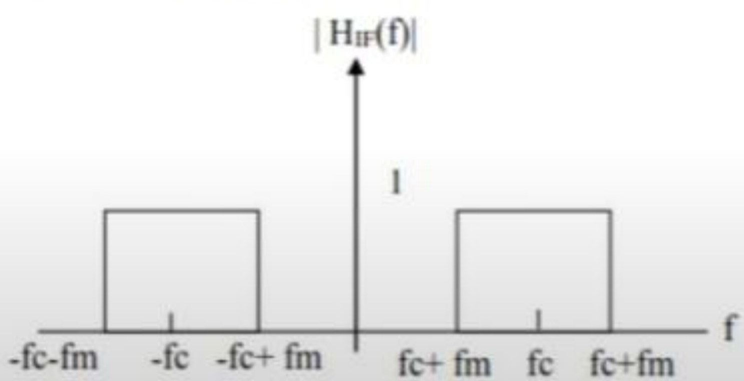
Noise in Amplitude Modulation

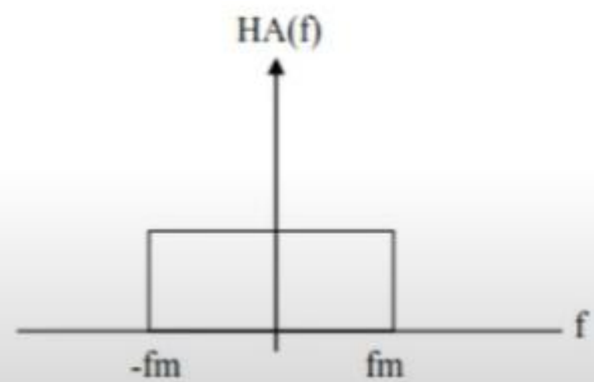
2- Double side band modulation:



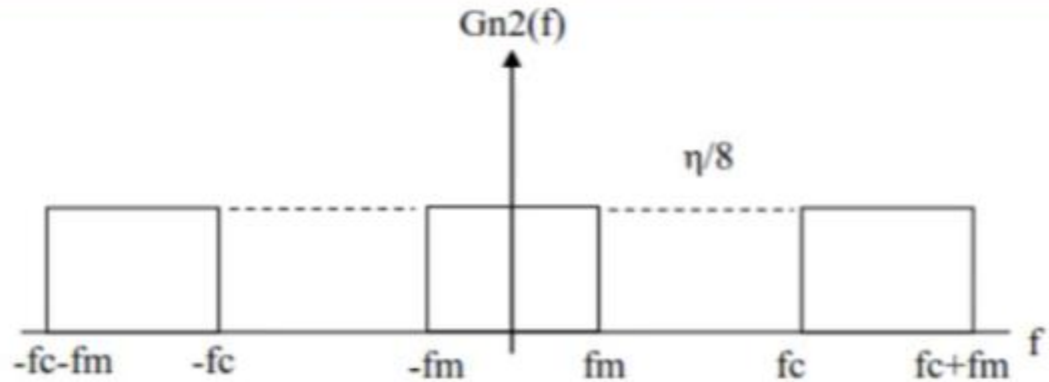
fc= f_{IF} intermediate freq.

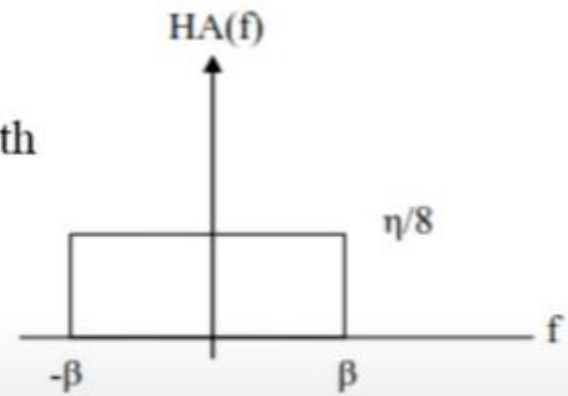
fm = baseband band width





Noise in Amplitude Modulation





N=PSD*Bw

Noise power = power spectral density * bandwidth

$$No = \frac{\eta}{8}.2\,fm = \frac{\eta fm}{4}$$

Calculation of signal to noise ratio:

$$\frac{So}{No} = \frac{Si/4}{\eta fm/4} = \frac{Si}{\eta fm}$$

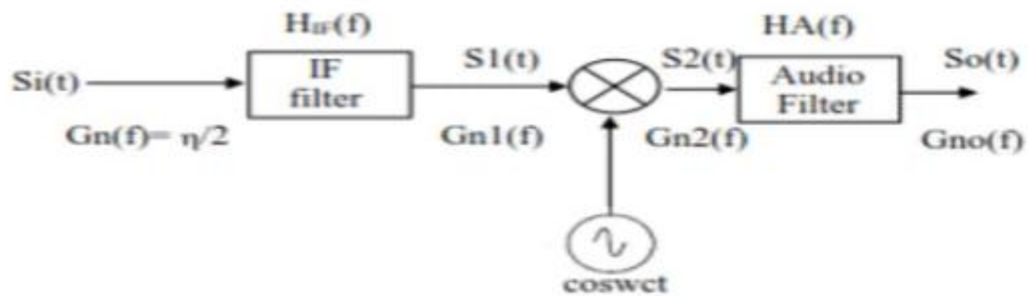
Noise in Amplitude Modulation

Calculation of Signal Power:

Assuming a sinusoidal base band signal of freq. fm. (f(t) = A coswmt).

To keep the received power the same as in the SSB case.

$Fi(t) = \sqrt{2}\, Ac \cos wct \cos wmt$



$F_1(t) = Fi(t)$

Multiplier o/p

$F_2(t) = F_1(t) \cos wct = [\sqrt{2}\, Ac \cos wct \cos wmt] \cos wct$

$= \sqrt{2}\, Ac \cos^2 wct \cos wmt = \frac{Ac}{\sqrt{2}} \cos wmt + \frac{Ac}{\sqrt{2}} \cos (2wc)t$

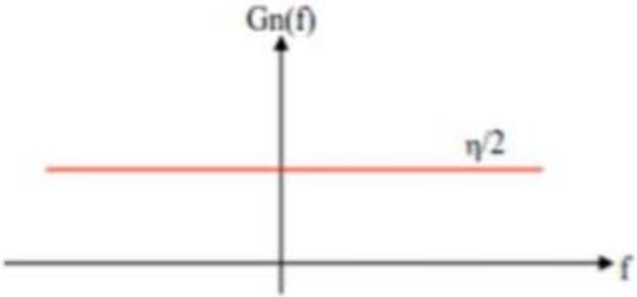
Output- signal $Fo(t) = \frac{Ac}{\sqrt{2}} \cos wmt$

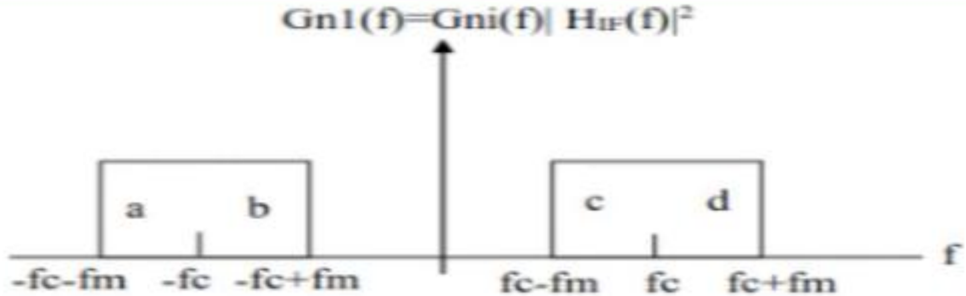
i/p signal power $Si = \frac{A^2c}{2}$

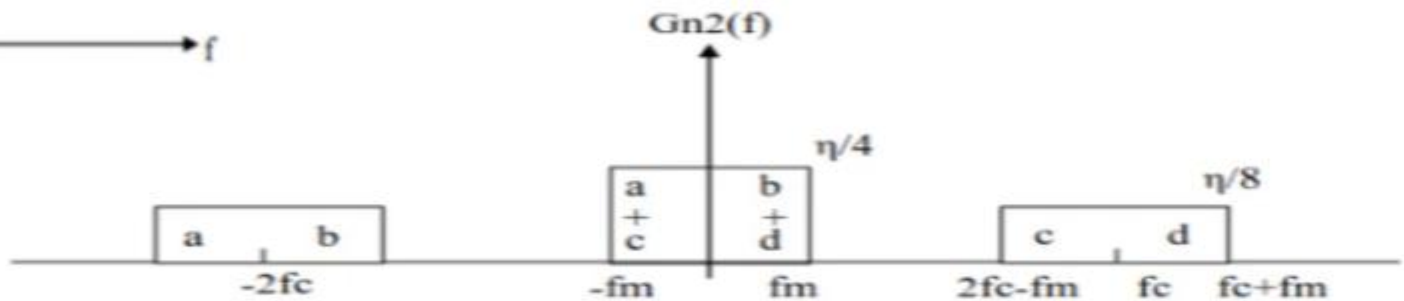
o/p signal power $So = Ac^2/4 = \frac{Si}{2}$

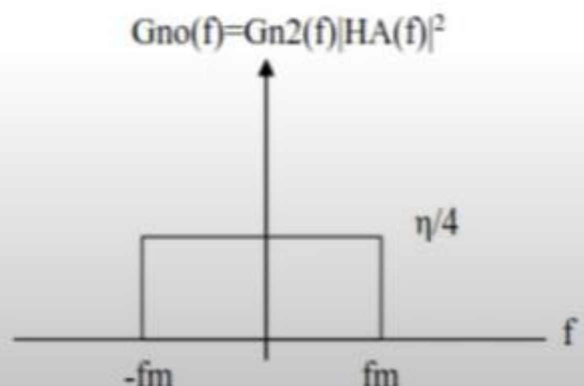
Noise in Amplitude Modulation

Calculation of Noise Power:









$$No = \frac{\eta}{4}.2\,fm = \frac{\eta fm}{2}$$

Calculation of signal to noise ratio:

$$\frac{So}{No} = \frac{Si/2}{\eta fm/2} = \frac{Si}{\eta fm}$$

Noise in Amplitude Modulation

3- Normal AM Modulation:

Assuming synchronous detection as in DSB & SSB the carrier is used as a transmitted reference to obtain the local oscillator signal the carrier increase the total input signal power but makes no contribution to the o/p signal power.

The So/No for DSB-SC applies directly to this case provided Si is replaced by Si

$$\frac{So}{No} = \frac{Si^{SB}}{\eta fm}, \qquad Si^{SB} = \text{power in side band alone}$$

Suppose the received signal is Si(t) = A[1+ mf(t)]coswct

= A cos wct + mAf(t)coswct

m= modulation index

f(t)= baseband (modulation signal) which amplitude modulates

The carrier is Acoswct

$Si = Pc + Si^{(SB)}$ (1)

Noise in Amplitude Modulation

where $Pc = \frac{A^2}{2}$ carrier power and

$$Si^{(SB)} = \frac{m^2 A_c^{\,2}\,\overline{f^2(t)}}{2} = \text{side band power}$$

Substitute in 1

$$Si = \frac{A_c^{\,2}}{2} + \frac{m^2 A_c^{\,2}\,\overline{f^2(t)}}{2}$$

$$\frac{A_c^{\,2}}{2} = \frac{Si}{1 + m^2\,\overline{f^2(t)}}$$ substitute this in sideband power.

$$Si^{(SB)} = \frac{m^2\,\overline{f^2(t)}}{1 + m^2\,\overline{f^2(t)}}\,Si$$

$$\frac{So}{No} = \frac{m^2\,\overline{f^2(t)}}{1 + m^2\,\overline{f^2(t)}} * \frac{Si}{\eta fm}$$

Noise in Amplitude Modulation

In terms of carrier power Pc

$$\frac{So}{No}=m^2\,\overline{f^2(t)}\,\frac{Pc}{\eta fm}$$

For sinusoidal modulation, f(t)= coswmt Si(t)= A(1+coswmt)coswct

$$m^2\,\overline{f^2(t)}=\frac{m^2}{2}$$

$$\therefore \frac{So}{No}=\frac{m^2}{2+m^2}\cdot\frac{Si}{\eta fm}$$

Noise in Amplitude Modulation

A Figure of Merit:

For the purpose of comparing systems a figure merit γ may be introduced where γ is defined by..

$$\boxed{\gamma = \frac{So/No}{Si/Nm}}$$

$$\gamma = \begin{cases} 1 & SSB \\ 1 & DSB-SC \\ \dfrac{m^2 \overline{f^2(t)}}{m^2 \overline{f^2(t)} + 1} & \text{normal AM} \\ \dfrac{m^2}{m^2 + 2} & \text{normal AM with sinusoidal modulation} \end{cases}$$

Example:

A received system works at $1\,\mathrm{MHz}$. The modulating signal power (Si) is $1\,\mathrm{mW}$ and its bandwidth (fm) is $3\,\mathrm{kHz}$. If the spectral density of noise power is $10^{-23}\,\mathrm{watt/Hz}$ (two-side), find Si/Ni and So/No for:

1. **DSB**
2. **SSB**

Solution:

Given:

- $Si = 1\,\mathrm{mW} = 1 \times 10^{-3}\,\mathrm{W}$
- $fm = 3\,\mathrm{kHz} = 3 \times 10^{3}\,\mathrm{Hz}$
- $fc = 1\,\mathrm{MHz}$
- $\eta/2 = 10^{-23}\,\mathrm{watt/Hz}$ (two side)

Solution

1) For DSB:

- **Noise Input (N_i):**

$$N_i = \frac{\eta}{2} \times 2f_m$$

$$N_i = 10^{-23}\ \text{watt/Hz} \times (2 \times 3 \times 10^3\ \text{Hz}) = \mathbf{6 \times 10^{-20}}\ \text{W}$$

- **Signal-to-Noise Ratio at Input (S_i / N_i):**

$$\frac{S_i}{N_i} = \frac{1\times10^{-3}}{6\times10^{-20}}$$

$$\frac{S_i}{N_i} = (\mathbf{1/6}) \times \mathbf{10^{17}}$$

- **Signal-to-Noise Ratio at Output (S_o / N_o):**

For **DSB**, $\frac{S_i}{N_i} = \frac{S_o}{N_o}$

$$\frac{S_o}{N_o} = (\mathbf{1/6}) \times \mathbf{10^{17}}$$

solution

2) For SSB:

- **Noise Input (N_i):**

$$N_i = \frac{\eta}{2} \times f_m$$

$$N_i = 10^{-23} \text{ watt/Hz} \times (3 \times 10^3 \text{ Hz}) = \mathbf{3 \times 10^{-20}} \text{ W}$$

- **Signal-to-Noise Ratio at Input (S_i / N_i):**

$$\frac{S_i}{N_i} = \frac{1 \times 10^{-3}}{3 \times 10^{-20}}$$

$$\frac{S_i}{N_i} = \mathbf{(1/3) \times 10^{17}}$$

- **Signal-to-Noise Ratio at Output (S_o / N_o):**

For **SSB**, $\frac{S_i}{N_i} = \frac{S_o}{N_o}$

$$\frac{S_o}{N_o} = \mathbf{(1/3) \times 10^{17}}$$