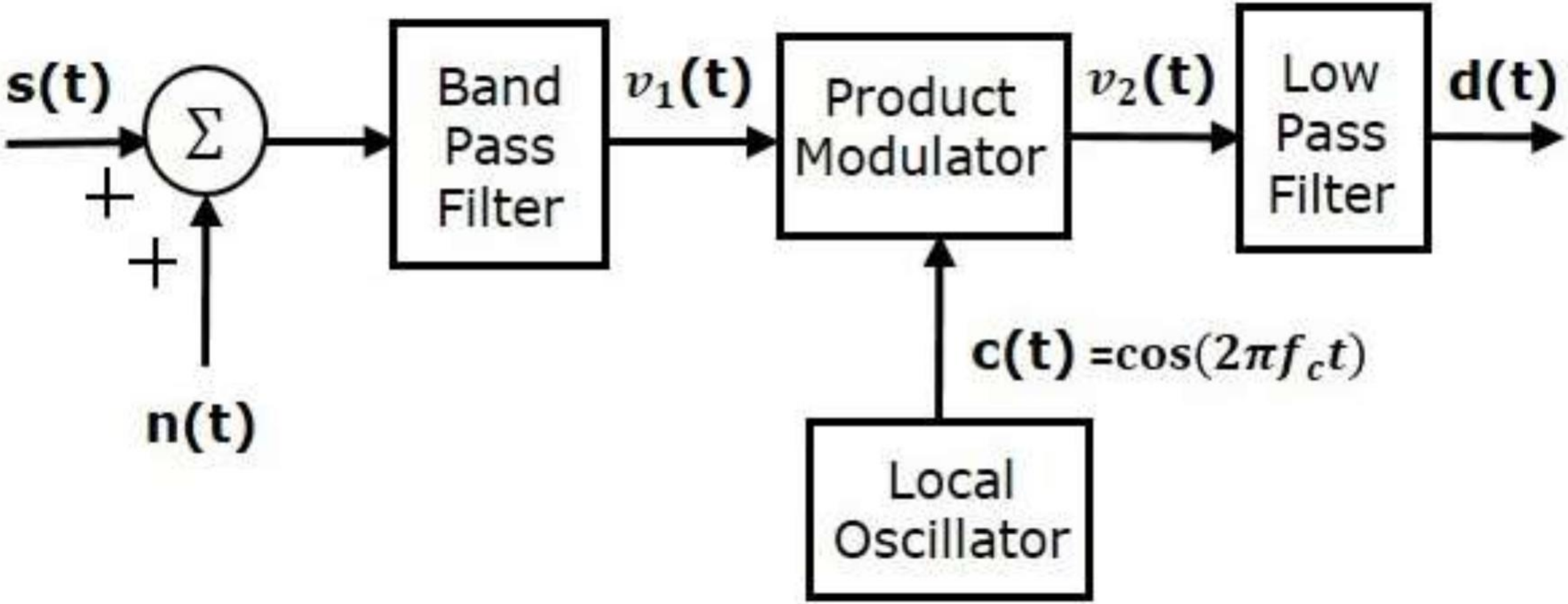
SNR Calculations in DSBSC System

Consider the following receiver model of DSBSC system to analyze noise.



We know that the DSBSC modulated wave is

$$\boldsymbol{s(t) = A_c\, \mathrm{m}(t) \cos(2\pi f_c t)}$$

Average power of DSBSC modulated wave is

$$\boldsymbol{P_s = \frac{A_c{}^2 P}{2}}$$

P is the power of the message signal $= \boldsymbol{Am^2/2}$

Average power of noise in the message bandwidth is

$$P_{nc} = WN_O$$

Substitute, these values in **channel SNR** formula.

$$(SNR)_{C,DSBSC} = \frac{\textbf{Average power of DSBSC modulated wave}}{\textbf{Average power of noise in message bandwidth}}$$

$$=> (SNR)_{C,DSBSC} = \frac{A_c{}^2 P}{2WN_O}$$

Assume the band pass noise is mixed with DSBSC modulated wave in the channel as shown in the above figure. This combination is applied as one of the input to the product modulator. Hence, the input of this product modulator is

$$v_1(t) = s(t) + n(t)$$

$$=> v_1(t) = A_c m(t) cos(2\pi f_c t) + [n_I(t) cos(2\pi f_c t) - n_Q(t) sin(2\pi f_c t)]$$

$$=> v_1(t) = [A_c m(t) + n_I(t)] cos(2\pi f_c t) - n_Q(t) sin(2\pi f_c t)$$

Local oscillator generates the carrier signal $c(t) = cos(2\pi fct)$. This signal is applied as another input to the product modulator. Therefore, the product modulator produces an output, which is the product of $v1(t)$ and $c(t)$.

$$v_2(t) = v_1(t)c(t)$$

Substitute, $v_1(t)$ and $c(t)$ values in the above equation.

$$=> v_2(t) = \left([A_c m(t) + n_I(t)]cos(2\pi f_c t) - n_Q(t)sin(2\pi f_c t)\right) cos(2\pi f_c t)$$

$$=> v_2(t) = [A_c m(t) + n_I(t)]\, cos^2(2\pi f_c t) - n_Q(t)sin(2\pi f_c t)cos(2\pi f_c t)$$

$$=> v_2(t) = [A_c m(t) + n_I(t)]\left(\frac{1 + cos(4\pi f_c t)}{2}\right) - n_Q(t)\frac{sin(4\pi f_c t)}{2}$$

$$v_2(t) = [A_c m(t) + n_I(t)]\left(\frac{1 + cos(4\pi f_c t)}{2}\right) - n_Q(t)\frac{sin(4\pi f_c t)}{2}$$

When the above signal is applied as an input to low pass filter, we will get the output of low pass filter as

$$v_2(t) = [A_c m(t) + n_I(t)]\left(\frac{1 + cos(4\pi f_c t)}{2}\right) - n_Q(t)\frac{sin(4\pi f_c t)}{2}$$

When the above signal is applied as an input to low pass filter, we will get the output of low pass filter as

$$d(t) = \frac{[A_c m(t) + n_I(t)]}{2}$$

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Average power of the demodulated signal is

$$P_m = \frac{{A_c}^2 P}{8}$$

Average power of noise at the output is

$$P_{no} = \frac{W N_O}{4}$$

Substitute, these values in **output SNR** formula.

$$(SNR)_{O,DSBSC} = \frac{\text{Average power of demodulated signal}}{\text{Average power of noise at output}}$$

$$\Rightarrow (SNR)_{O,DSBSC} = \left(\frac{{A_c}^2 P}{8}\right) \Big/ \left(\frac{WN_O}{4}\right) = \frac{{A_c}^2 P}{2WN_O}$$

Substitute, the values in **Figure of merit** of DSBSC receiver formula

$$F = \frac{(SNR)_{O,DSBSC}}{(SNR)_{c,DSBSC}}$$

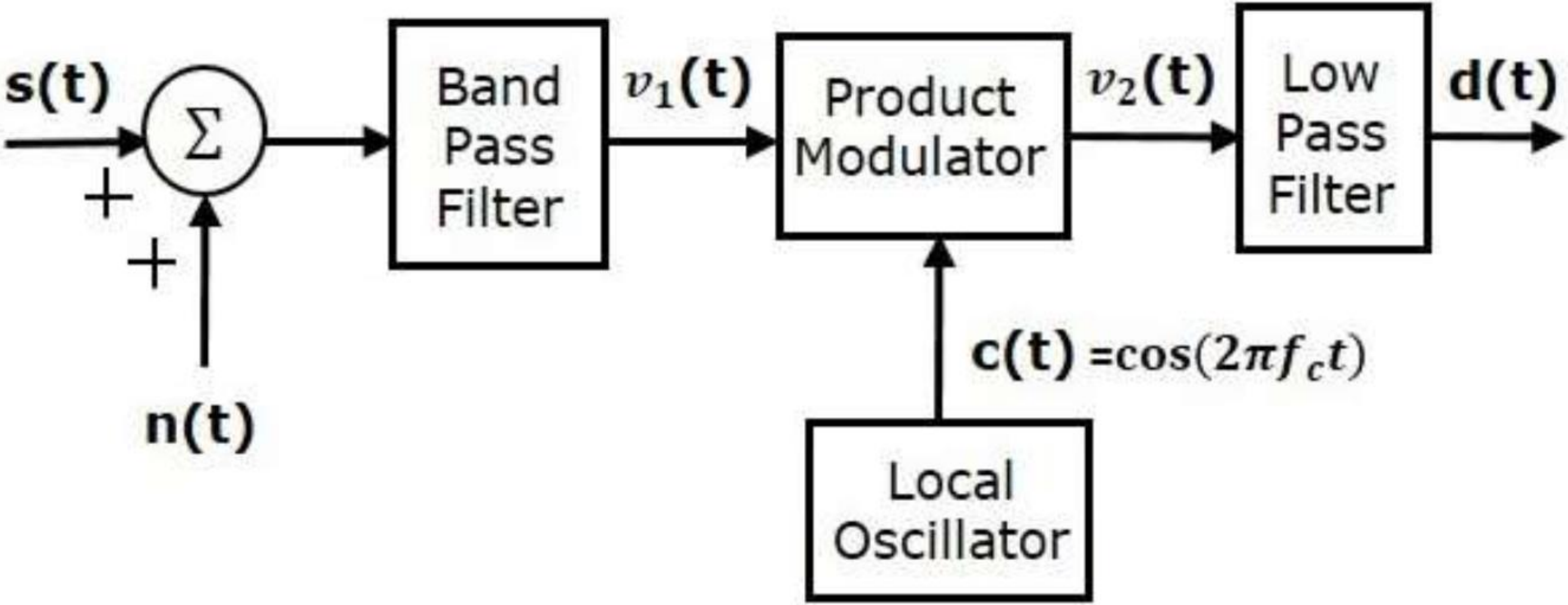
$$=> F = \left(\frac{{A_c}^2 P}{2WN_O}\right) \Big/ \left(\frac{{A_c}^2 P}{2WN_O}\right)$$

$$=> F = 1$$

Therefore, the Figure of merit of DSBSC receiver is 1.

SNR Calculations in SSBSC System

Consider the following receiver model of SSBSC system to analyze noise.



We know that the SSBSC modulated wave having lower sideband is

$$s(t) = \frac{A_m A_c}{2} \cos[2\pi(f_c - f_m)t]$$

Average power of SSBSC modulated wave is

$$P_s = \left(\frac{A_m A_c}{2\sqrt{2}}\right)^2 = \frac{{A_m}^2 {A_c}^2}{8}$$

Average power of noise in the message bandwidth is

$$P_{nc} = WN_0$$

Substitute, these values in **channel SNR** formula.

$$(SNR)_{C,SSBSC} = \frac{\textbf{Average power of SSBSC modulated wave}}{\textbf{Average power of noise in message bandwidth}}$$

$$=> (SNR)_{C,SSBSC} = \frac{{A_m}^2 {A_c}^2}{8WN_O}$$

Assume the band pass noise is mixed with SSBSC modulated wave in the channel as shown in the above figure. This combination is applied as one of the input to the product modulator. Hence, the input of this product modulator is

$$v_1(t) = s(t) + n(t)$$

$$=> v_1(t) = \frac{A_m A_c}{2} \cos[2\pi(f_c - f_m)t] + n_I(t)cos(2\pi f_c t) - n_Q(t)sin(2\pi f_c t)$$

The local oscillator generates the carrier signal $\boldsymbol{c(t) = cos(2\pi fct)}$. This signal is applied as another input to the product modulator. Therefore, the product modulator produces an output, which is the product of $\boldsymbol{v1(t)}$ and $c(\boldsymbol{t})$.

$$\boldsymbol{v_2(t) = v_1(t)c(t)}$$

Substitute, $\boldsymbol{v_1(t)}$ and $\boldsymbol{c(t)}$ values in the above equation.

$$\Rightarrow \boldsymbol{v_2(t) = \left(\frac{A_m A_c}{2}\cos[2\pi(f_c - f_m)t] + n_I(t)cos(2\pi f_c t) - n_Q(t)sin(2\pi f_c t)\right) cos(2\pi f_c t)}$$

$$\Rightarrow \boldsymbol{v_2(t) = \frac{A_m A_c}{2}\cos[2\pi(f_c - f_m)t]\,cos(2\pi f_c t) + n_I(t)cos^2(2\pi f_c t) - n_Q(t)sin(2\pi f_c t)cos(2\pi f_c t)}$$

$$\Rightarrow \boldsymbol{v_2(t) = \frac{A_m A_c}{4}\{\cos[2\pi(2f_c - f_m)t] + \cos(2\pi f_m t)\} + n_I(t)\left(\frac{1 + cos(4\pi f_c t)}{2}\right) - n_Q(t)\frac{sin(4\pi f_c t)}{2}}$$

$$v_2(t) = \frac{A_m A_c}{4}\{\cos[2\pi(2f_c - f_m)t] + \cos(2\pi f_m t)\} + n_I(t)\left(\frac{1 + \cos(4\pi f_c t)}{2}\right) - n_Q(t)\frac{\sin(4\pi f_c t)}{2}$$

When the above signal is applied as an input to low pass filter, we will get the output of low pass filter as

$$d(t) = \frac{A_m A_c}{4}\cos(2\pi f_m t) + \frac{n_I(t)}{2}$$

Average power of the demodulated signal is

$$P_m = \frac{{A_m}^2 {A_c}^2}{32}$$

Average power of noise at the output is

$$P_{no} = \frac{W N_0}{4}$$

Substitute, these values in **output SNR** formula

$$(SNR)_{O,SSBSC} = \frac{\text{Average power of demodulated signal}}{\text{Average power of noise at output}}$$

$$=> (SNR)_{O,SSBSC} = \left(\frac{{A_m}^2{A_c}^2}{32}\right) \Big/ \left(\frac{WN_O}{4}\right) = \frac{{A_m}^2{A_c}^2}{8WN_O}$$

Substitute, the values in **Figure of merit** of SSBSC receiver formula

$$F = \frac{(SNR)_{O,SSBSC}}{(SNR)_{c,SSBSC}}$$

$$=> \boldsymbol{F} = \left(\frac{\boldsymbol{A_m}^2 \boldsymbol{A_c}^2}{\boldsymbol{8WN_O}}\right) \Big/ \left(\frac{\boldsymbol{A_m}^2 \boldsymbol{A_c}^2}{\boldsymbol{8WN_O}}\right)$$

$$=> \boldsymbol{F} = \boldsymbol{1}$$

Therefore, the Figure of merit of SSBSC receiver is 1.

Two resistors, 5 kohm and 20 kohm, are at 27°C. Calculate the thermal noise power and voltage for a 10 kHz bandwidth

for each resistor

for their series combination

for their parallel combination

A direct current of 100mA flows across a semiconductor junction. If the effective noise bandwidth is specified as 1MHz, determine the mean-square shot noise current

A direct current of 100mA flows across a semiconductor junction. If the effective noise bandwidth is specified as 1MHz, determine the mean-square shot noise current

$$I_s^2 = 2 \times (100 \times 10^{-3}) \times (1.6 \times 10^{-19}) \times (1 \times 10^{6})$$

$$I_s^2 = \mathbf{0.18 \times 10^{-6}\ amperes}$$

Considering thermal noise only, what is the effect on the signal-to-noise power ratio of a system of doubling its bandwidth? Assume all other conditions remain same.