Ejercicio 4

Un sistema de comunicaciones tiene 100 dB de atenuación en el enlace, una densidad espectral de ruido a la entrada de $2{,}54.10^{-18}$ W/Hz y un ancho de banda equivalente de ruido 10% por encima del estricto necesario previo a la demodulación. Complete la siguiente tabla con las <u>ecuaciones</u> de las potencias de señal y de ruido a la entrada y a la salida del detector y los valores de ancho de banda y potencia de señal transmitida para obtener una relación señal a ruido a la salida del detector de 40 dB, para mensajes con anchos de banda de 5 kHz y 10 kHz cuya relación de potencia media a potencia máxima instantánea es de 0,125.

Tabla

<table>
<tr><th rowspan="2">Modulación</th><th colspan="2">Potencia de Señal</th><th colspan="2">Potencia de Ruido</th><th rowspan="2">¿Verifica Umbral?</th><th rowspan="2">$B_T[KHz]$</th><th rowspan="2">$P_{S_T}\ [dBm]$</th></tr>
<tr><th>Entrada</th><th>Salida</th><th>Entrada</th><th>Salida</th></tr>
<tr><td rowspan="2">Banda base</td><td colspan="2" rowspan="2">$P_S = \frac{A_c^2}{2}$</td><td colspan="2" rowspan="2">$P_N = N_0.1{,}1.B_T$</td><td rowspan="2">-</td><td>5</td><td>1,5</td></tr>
<tr><td>10</td><td>4,5</td></tr>
<tr><td rowspan="2">SSB</td><td colspan="2" rowspan="2">$P_S = \frac{A_c^2.\langle m_{(t)}^2\rangle}{2}$</td><td colspan="2" rowspan="2">$P_N = N_0.1{,}1.B_T$</td><td rowspan="2">-</td><td>5</td><td>1,5</td></tr>
<tr><td>10</td><td>4,5</td></tr>
<tr><td rowspan="2">DSB-SC</td><td colspan="2" rowspan="2">$P_S = \frac{A_c^2.\langle m_{(t)}^2\rangle}{2}$</td><td colspan="2" rowspan="2">$P_N = N_0.1{,}1.(2.B_T)$</td><td rowspan="2">-</td><td>5</td><td>4,5</td></tr>
<tr><td>10</td><td>7,5</td></tr>
<tr><td rowspan="2">AM
$(m = 95\%)$</td><td colspan="2" rowspan="2">$P_S = \frac{A_c^2.[1+\langle m_{(t)}^2\rangle]}{2}$</td><td colspan="2" rowspan="2">$P_N = N_0.1{,}1.(2.B_T)$</td><td>Si</td><td>5</td><td>4,5</td></tr>
<tr><td>Si</td><td>10</td><td>7,5</td></tr>
<tr><td rowspan="2">PM
$(\Delta\theta = \pi)$</td><td rowspan="2">$P_S = \frac{A_c^2}{2}$</td><td rowspan="2">$P_S = K^2.D_p^2.\langle m_{(t)}^2\rangle$</td><td rowspan="2">$P_N = N_0.1{,}1.B_T$</td><td rowspan="2">$P_N = \frac{2.K^2.N_0.1{,}1.B_T}{A_c^2}$</td><td>Si</td><td>5</td><td>-5,63</td></tr>
<tr><td>Si</td><td>10</td><td>-2,63</td></tr>
<tr><td rowspan="2">FM
$(\Delta f = 75KHz)$</td><td rowspan="2">$P_S = \frac{A_c^2}{2}$</td><td rowspan="2">$P_S = K^2.D_f^2.\langle m_{(t)}^2\rangle$</td><td rowspan="2">$P_N = N_0.1{,}1.B_T$</td><td rowspan="2">$P_N = \frac{2}{3}.\left(\frac{K}{A_c}\right)^2.N_0.(1{,}1.B_T)^3$</td><td>No</td><td>5</td><td>-29,87</td></tr>
<tr><td>Si</td><td>10</td><td>-18,06</td></tr>
<tr><td rowspan="2">FM Deénfasis
$\begin{pmatrix}\Delta f = 75KHz \\ RC = 75\mu S\end{pmatrix}$</td><td rowspan="2">$P_S = \frac{A_c^2}{2}$</td><td rowspan="2">$P_S = K^2.D_f^2.\langle m_{(t)}^2\rangle$</td><td rowspan="2">$P_N = N_0.1{,}1.B_T$</td><td rowspan="2">$P_N = \frac{2.K^2.N_0.f_1^2.(1{,}1.B_T)}{A_c^2}$</td><td>Si</td><td>5</td><td>-16,57</td></tr>
<tr><td>Si</td><td>10</td><td>-10,8</td></tr>
</table>

Banda base / SSB

$$SNR_D = \frac{P_S}{P_N} = \frac{P_S}{N_0.1,1.B_T}$$

$P_S = SNR_D.N_0.1,1.B_T$

Para $B_T = 5KHz$:

$P_S = 1,4x10^{-10}W = -98,5dB$

$P_{ST} = P_S + 100dB = 1,5dB$

Para $B_T = 10KHz$:

$P_S = 2,8x10^{-10}W = -95,5dB$

$P_{ST} = P_S + 100dB = 4,5dB$

DSB-SC / AM

$SNR_D = \frac{P_S}{P_N} = \frac{P_S}{N_0.1,1.2.B_T}$

$P_S = SNR_D.N_0.1,1.2.B_T$

Para $B_T = 5KHz$:

$P_S = 2,8x10^{-10}W = -95,5dB$

$P_{ST} = P_S + 100dB = 4,5dB$

Para $B_T = 10KHz$:

$P_S = 5,6x10^{-10}W = -92,5dB$

$P_{ST} = P_S + 100dB = 7,5dB$

PM

$\beta_p = \pi$

$\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle = \frac{1}{2.(FC)^2} = \frac{1}{16}$

$\frac{SNR_D}{SNR_R} = 2.\beta_p^2.(\beta_p + 1).\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle$

$SNR_R = \frac{SNR_D}{2.\beta_p^2.(\beta_p + 1).\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle} = 1957,14 = 32,9dB$

$SNR_R = \frac{P_S}{P_N} = \frac{P_S}{N_0.1,1.B_T}$

$P_S = SNR_R.N_0.1,1.B_T$

Para $B_T = 5KHz$:

$P_S = 2,73x10^{-11} = -105,63dB$

$P_{ST} = P_S + 100dB = -5,63dB$

Para $B_T = 10KHz$:

$P_S = 5,46x10^{-11} = -102,63dB$

$P_{ST} = P_S + 100dB = -2,63dB$

FM

$\Delta_f = 75KHz$

$\beta_{f\,B_T=5KHz} = \frac{75KHz}{5KHz} = 15$

$$\beta_{f_{B_T=10KHz}} = \frac{75KHz}{10KHz} = 7.5$$

$$\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle = \frac{1}{2.(FC)^2} = \frac{1}{16}$$

$$\frac{SNR_D}{SNR_R} = 6.\beta_f^2.(\beta_f + 1).\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle$$

$$SNR_R = \frac{P_S}{N_0.1,1.B_T}$$

$P_S = N_0.1,1.B_T.SNR_R$

Para $B_T = 5KHz$

$SNR_R = 7,4 = 8,7dB$

$P_S = 1,03x10^{-13} = -129,87dB$

$P_{ST} = P_S + 100dB = -29,87dB$

Para $B_T = 10KHz$

$SNR_R = 55,77 = 17,46dB$

$P_S = 1,56x10^{-12} = -118,06dB$

$P_{ST} = P_S + 100dB = -18,06dB$

FM

$\Delta_f = 75KHz$

$$\beta_{f_{B_T=5KHz}} = \frac{75KHz}{5KHz} = 15$$

$$\beta_{f_{B_T=10KHz}} = \frac{75KHz}{10KHz} = 7.5$$

$$\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle = \frac{1}{2.(FC)^2} = \frac{1}{16}$$

$$f_1 = \frac{1}{R.C} = 13,33KHz$$

$$\frac{SNR_D}{SNR_R} = 2.\beta_f^2.(\beta_f + 1).\left(\frac{B}{f_1}\right).\left\langle \frac{m_{(t)}^2}{V_p^2} \right\rangle$$

$$SNR_R = \frac{P_S}{N_0.1,1.B_T}$$

$P_S = N_0.1,1.B_T.SNR_R$

Para $B_T = 5KHz$

$SNR_R = 157,94 = 21,98dB$

$P_S = 2,2x10^{-12} = -116,57dB$

$P_{ST} = P_S + 100dB = -16,57dB$

Para $B_T = 10KHz$

$SNR_R = 297,31 = 24,73dB$

$P_S = 8,3x10^{-12} = -110,8dB$

$P_{ST} = P_S + 100dB = -10,8dB$