1)

①

TF sistema 3x3

$$c = \begin{bmatrix} 1+j \\ 1-j \\ 1+j \end{bmatrix} \qquad H = \begin{bmatrix} 0{,}2e^{-j0{,}5} & 0{,}8e^{-j1{,}2} & 1{,}1e^{+j\pi/3} \\ 0{,}6 & 0{,}1e^{-j\pi} & 1{,}3e^{-j\pi/4} \\ 0{,}3e^{-j\pi/3} & e^{-j\pi/5} & 0{,}4e^{-j} \end{bmatrix}$$

$$n = \begin{bmatrix} 0{,}1+j0{,}2 \\ 0{,}2-j0{,}1 \\ 0{,}2 \end{bmatrix}$$

$$y = H \cdot C + n$$

$$A = H \cdot C \Rightarrow \begin{bmatrix} 0{,}2e^{-j0{,}5} & 0{,}8e^{-j1{,}2} & 1{,}2e^{+j\pi/3} \\ 0{,}6 & 0{,}2e^{-j\pi} & 1{,}3e^{-j\pi/4} \\ 0{,}3e^{-j\pi/3} & e^{-j\pi/5} & 0{,}4 \cdot e^{-j} \end{bmatrix} \begin{bmatrix} 1+j \\ 1-j \\ 1+j \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} 0{,}1755-0{,}095j & 0{,}28-0{,}75j & 0{,}55+0{,}95j \\ 0{,}6 & -0{,}1 & 0{,}91-0{,}91j \\ 0{,}15-0{,}25j & 0{,}8-0{,}58 & 0{,}21-0{,}33 \end{bmatrix} \begin{bmatrix} 1+j \\ 1-1 \\ 1+j \end{bmatrix}$$

$$y = A - \Rightarrow \begin{bmatrix} -0{,}58+0{,}54 \\ 2{,}33+0{,}7i \\ 1{,}18-1{,}62 \end{bmatrix} + \begin{bmatrix} \end{bmatrix}$$

$$y = A + n = \begin{bmatrix} -0{,}58+0{,}54 \\ 2{,}33+0{,}7i \\ 1{,}18-1{,}62 \end{bmatrix} + \begin{bmatrix} 0{,}1+j0{,}2 \\ 0{,}2-j0{,}1 \\ 0{,}2 \end{bmatrix}$$

$$y = \begin{bmatrix} -0{,}4870+0{,}1746i \\ 2{,}5395+0{,}6i \\ 1{,}3837-1{,}6271i \end{bmatrix}$$

Usando ZF $\hat{c} = H^{-1} y$ ②

$\det(H) \neq 0$ portanto H possui inversa.

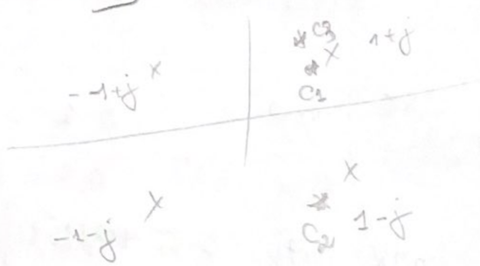
$$H^{-1} = \begin{bmatrix} 1{,}0589 + 1{,}2147i & 1{,}5684 - 0{,}5739i & -1{,}0762 - 0{,}314i \\ -0{,}3388 + 0{,}0817i & -0{,}8218 + 0{,}2415i & 0{,}9614 - 0{,}3868i \\ 0{,}0286 - 0{,}7553i & -0{,}1859 + 0{,}215i & 0{,}28 + 0{,}527i \end{bmatrix}$$

(procedimento de matriz na pagina ③)

$$\hat{c} = H^{-1} \cdot \begin{bmatrix} -0{,}487 + 0{,}7467i \\ 2{,}5385 + 0{,}0i \\ 1{,}3837 - 1{,}6207i \end{bmatrix}$$

$$= \begin{bmatrix} 0{,}9038 + 0{,}9984i \\ 1{,}1018 - 0{,}9098i \\ 1{,}1943 + 1{,}0972i \end{bmatrix}$$

Usando 4PSK




Usando ML para estimar o símbolo

$$C = \begin{bmatrix} 1+j \\ 1-j \\ 1+j \end{bmatrix}$$

③

$$\det = \Big[ (0{,}17-0{,}09 \, (-0{,}1 \times 0{,}21 - 0{,}31) + (0{,}28-0{,}75)(0{,}91-0{,}91)(0{,}15-0{,}25) + (0{,}55+0{,}95i)(0{,}6)(0{,}8 - 0{,}58) \Big] - \Big[ (0{,}55+0{,}95i)(-0{,}1)(0{,}15-0{,}25i) + (0{,}88-0{,}75)(0{,}6) + 0{,}21-0{,}31i) + (0{,}17-0{,}9i)(+0{,}8-0{,}58i)(0{,}91-0{,}91i)$$

$$\det(H) = 0{,}5256 + 0{,}6426i$$

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Elementos da matriz cofactor

fila 1 $H_{00} = (-1)^{0+0} \begin{vmatrix} -0{,}1-0i & 0{,}91-0{,}91i \\ 0{,}8-0{,}8i & 0{,}21-0{,}33i \end{vmatrix} = -0{,}225+1{,}32j$

$H_{01} = (-1)^{1+0} \begin{vmatrix} 0{,}6 & 0{,}91-0{,}91 \\ 0{,}15-0{,}25 & 0{,}21-0{,}33 \end{vmatrix} = -0{,}23-0{,}1747j$

$H_{02} = (-1)^{2+0} \begin{vmatrix} 0{,}6 & 0{,}1 \\ 0{,}15-0{,}25 & 0{,}8-0{,}58i \end{vmatrix} = 0{,}5-0{,}3782j$

fila 2 $H_{10} = (-1)^{1+0} \cdot \begin{vmatrix} 0{,}28-0{,}17i & 0{,}55+0{,}95i \\ 0{,}8-0{,}88i & 0{,}21-0{,}33i \end{vmatrix} = 1{,}19+0{,}705i$

$H_{11} = (-1)^{1+2} \cdot \begin{vmatrix} 0{,}17-0{,}09i & 0{,}55+0{,}95i \\ 0{,}15-0{,}25i & 0{,}21-0{,}33i \end{vmatrix} = -0{,}32-0{,}079i$

$H_{12} = (-1)^{1+2} \cdot \begin{vmatrix} 0{,}17-0{,}09i & 0{,}28-0{,}74 \\ 0{,}17-0{,}25i & 0{,}8-0{,}88 \end{vmatrix} = -0{,}23-8{,}2i$

fila 3 $H_{20} = (-1)^{2+0} \cdot \begin{vmatrix} 0{,}28-0{,}17i & 0{,}55+0{,}95 \\ -0{,}1 & 0{,}91-0{,}91 \end{vmatrix} = -0{,}36-0{,}95i$

$H_{21} = (-1)^{2+1} \cdot \begin{vmatrix} 0{,}17-0{,}095 & 0{,}55+0{,}95 \\ 0{,}6 & 0{,}91-0{,}91 \end{vmatrix} = 0{,}25+0{,}82i$

$H_{22} = (-1)^{2+2} \cdot \begin{vmatrix} 0{,}17-0{,}095 & 0{,}28-0{,}74 \\ 0{,}6 & -0{,}1 \end{vmatrix} = -0{,}1913+0{,}456$

$$H^{-1} = \frac{1}{\det(H)} \begin{pmatrix} H_{00} & H_{01} & H_{02} \\ H_{10} & H_{11} & H_{12} \\ H_{21} & H_{21} & H_{22} \end{pmatrix}$$

Portanto $$H_i^{-1} = \begin{bmatrix} 1{,}05 + 1{,}22\,i & 1{,}56 - 0{,}57\,i & -1{,}07 - 0{,}31\,i \\ -0{,}338 + 0{,}08\,i & -0{,}32 + 0{,}25\,i & 0{,}96 + 0{,}38\,i \\ 0{,}028 - 0{,}77\,i & -0{,}105 + 0{,}21 & 0{,}28 + 0{,}52\,i \end{bmatrix}$$