1. (100%) Consider the two MIMO STCs: ABBA and D-STTD. Basic assumptions and some parameters are given as follows:

ABBA D-STTD

- Four antennas are adopted at Tx. However, one and two antennas are adopted at Rx for ABBA scheme and D-STTD scheme, respectively. When fixed modulation is used for each data stream, spectral efficiency of these coding schemes would be different due to different code rates.
- Channel gain of each link is assumed to be flat Rayleigh fading.
- 4-QAM modulation is adopted for each data stream.
- MMSE-OSIC receiver is adopted at Rx for each coding scheme to separate different data symbols based on the respective received signal model.

Plot the average BER (i.e., BER averaged over different data streams) versus received SNR curve and comment on your result. The range of SNR is -15 dB ~ 15 dB with a step of 3 dB.

Note: Numbers of transmitted data streams in ABBA and D-STTD are 1 and 2, respectively. However, in the decoding stage, all schemes need to separate four data streams

參數設定

- Tx天線數：4
- Rx天線數：
  - ABBA 1
  - D-STTD 2
- Channel model：每個link channel gain 為flat Rayleigh fading
- Modulation：4-QAM
- Receiver：MMSE-OSIC

MMSE-OSIC

Step 1 Nulling $W = H(H^H H + \frac{N}{SNR} I_M)^{-1}$ ，$z_{o_i}(k) = w_{o_i}^H y_{(i-1)}(k)$

Step 2 Symbol decision $\hat{x}_{o_i}(k) = dec(z_{o_i}(k))$

Step 3 order SIC $y_{(i)}(k) = y_{(i-1)}(k) - h_{o_i}\hat{x}_{o_i}(k)$

重複step 1~3 直到decode完

HW4 WCSP

ABBA code

$$\mathbf{z} = \mathbf{H}^H\mathbf{y} = \mathbf{G}\mathbf{s} + \mathbf{H}^H\mathbf{n}$$

$$\mathbf{G} = \mathbf{H}^H\mathbf{H} = \left[\begin{array}{cc|cc} \rho & 0 & \beta & 0 \\ 0 & \rho & 0 & \beta \\ \hline \beta & 0 & \rho & 0 \\ 0 & \beta & 0 & \rho \end{array}\right]$$

D-STTD
和P83比
變乾淨了
干擾要去掉的減少了

$$\rho = \sum_{n=1}^{4} \left|h_n\right|^2$$

- $\beta = 2\mathrm{Re}\{h_1{}^*h_3 + h_2{}^*h_4\}$: interference term

DSSTD code

$$\mathbf{z} = \mathbf{H}^H\mathbf{y} = \mathbf{G}\mathbf{s} + \mathbf{H}^H\mathbf{n}$$

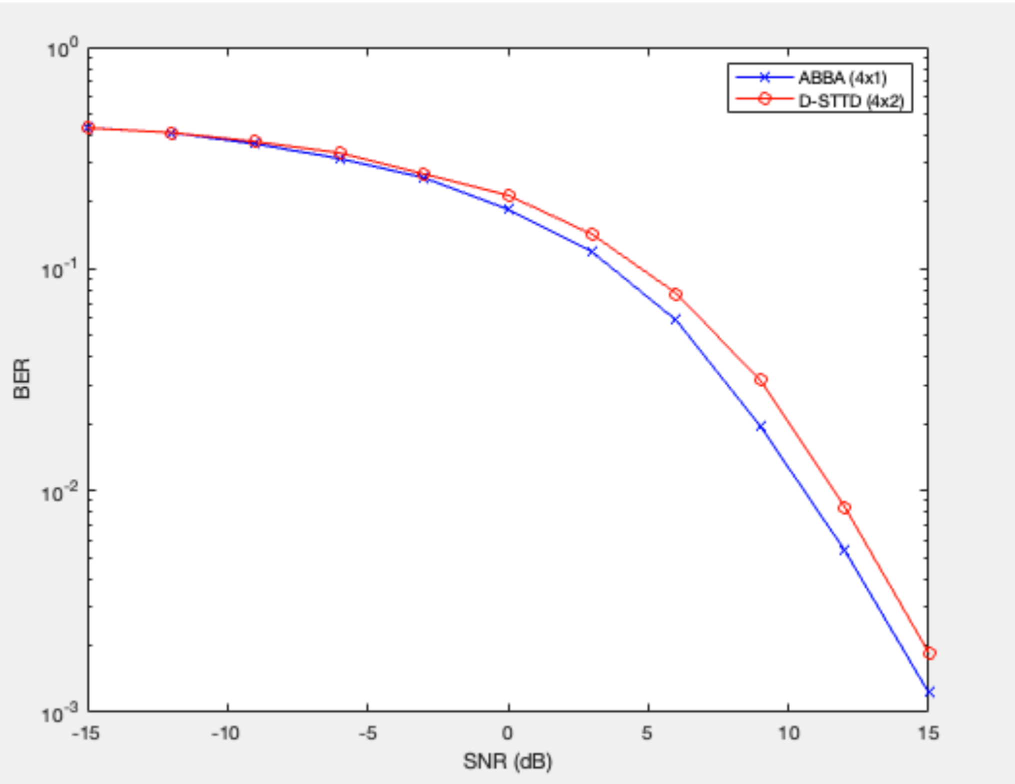
正交　非正交　非对角矩阵

$$\mathbf{G} = \mathbf{H}^H\mathbf{H} = \begin{bmatrix} \mathbf{H}_1^H\mathbf{H}_1 & \mathbf{H}_1^H\mathbf{H}_2 \\ \mathbf{H}_2^H\mathbf{H}_1 & \mathbf{H}_2^H\mathbf{H}_2 \end{bmatrix} = \left[\begin{array}{cc|cc} \rho_1 & 0 & \alpha & \beta \\ 0 & \rho_1 & -\beta^* & \alpha^* \\ \hline \alpha^* & -\beta & \rho_2 & 0 \\ \beta^* & \alpha & 0 & \rho_2 \end{array}\right]$$

$$\rho_i = \sum_{m=1}^{2} \left|h_{m,2i-1}\right|^2 + \left|h_{m,2i}\right|^2$$

- α and β : interference terms

結果：



HW4 WCSP

comment：

(1)從模擬結果可見，在低 SNR 區（–15 ~ 0 dB）時，ABBA 和 D–STTD 的 BER 幾乎相同。但在中高 SNR（3 dB 以上）時，ABBA 的BER下降明顯快於 D–STTD。

- ABBA 每次只傳一個stream，干擾小。
- D–STTD 雖然用兩根接收天線，但同時傳兩個stream，讓 MMSE–OSIC 難以完全消除干擾，所以BER會表現得比ABBA略差

(2)從圖上可以觀察到兩個的diversity order相同（斜率）

(3)但從data rate下去看，ABBA rate = 1，D–STTD rate = 2，在頻譜efficiency與資料傳輸量上，D–STTD 有優勢(trade off 效能、Pe ）。

- 以 SNR = 9 dB 為例，ABBA 的 BER 約為10^{-3}，而 D–STTD 約為2×10^{-3}，可見 BER 相差約一倍。而若將 data rate 納入考量，雖然 D–STTD BER 較差，但其傳輸資料量為 ABBA 的兩倍，若加上 error correction coding，整體 throughput 仍可能優於 ABBA。

(4)receiver 也可以搭配使用sphere decoder 或 ML 改善效能