Technical University of Crete
School of Electrical and Computer Engineering
Course: **Wireless Communications 2022-2023**
Exercise 2 (120/1000)
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Part 1 **1** The block fading channels are created as described below:

```
h = zeros(M,N);
for div = 1 : M
        h(div,:) = (randn(1,N) + 1i*randn(1,N))*sqrt(1/2);
end
```

Where M the desired diversity, meaning the number of receive antennae.

2 The transmitted 4-QAM symbols are created as described below:

```
s = 1 - (randi(2,[1,N])-1)*2 + 1i*(  1 - (randi(2,[1,N])-1)*2  );
```

3 The White Gaussian noise is created as described below:

```
n = zeros(M,N);
for div = 1:M
        n(div,:) = ( randn(1,N) + 1i*randn(1,N) )*sqrt(N_0/2);
end
```

Therefore the received signal on each antenna is:

```
r = zeros(M,N);
for div = 1:M
        r(div,:) = h(div,:).*s + n(div,:);
end
```

The transmitted signal power:

$$P_{TX} = \mathcal{E}[s^2] = \frac{1}{N}\sum_{i=1}^{N}|s_i|^2 = \frac{1}{N}\sum_{i=1}^{N}|\pm 1 \pm i|^2 = \frac{1}{N}\sum_{i=1}^{N} 2 = 2$$

Therefore the SNR in this case:

$$SNR_{db} = 10log_{10}\frac{P_{TX}}{P_{noise}} = 10log_{10}\frac{2}{N_0}$$

In order to get the desired SNR:

$$N_0 = \frac{2}{10^{\frac{SNR_{db}}{10}}}$$

4 Using the Maximum Ratio Combining(MRC) method we define:

$$R \coloneqq \frac{\mathbf{h}^H}{||\mathbf{h}||}\mathbf{Y}$$

and decide using the Maximum Likelihood(ML) method

$$\mathbf{x}^* = \underset{\mathbf{X}}{min}||\mathbf{R} - \mathbf{X}||^2$$

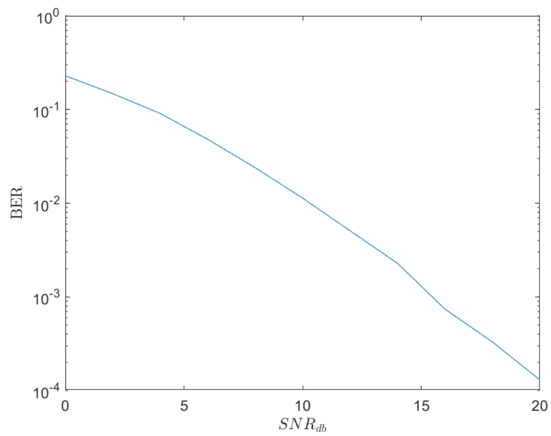

Figure 1: MRC method: BER for $SNR_{db} = [0:2:20]$

5

6 The theoretical BER:

$$BER_{Theoretical} = \binom{2M-1}{M} \frac{1}{4^M SNR_{db}^M}$$

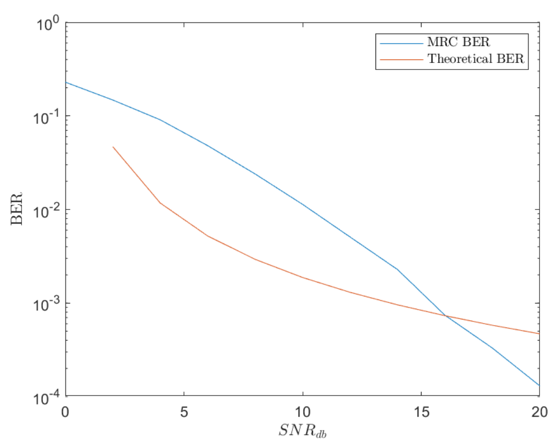

Figure 2: MRC method: Experimental and Theoretical BER for $SNR_{db} = [0:2:20]$

7

- Steps 1-2 are executed the same as before.
- In the Transmit Beamforming method the received signal is considered to be:

$$Y = ||\mathbf{h}||X + W$$

- Using ML we decide the received signal:

$$\mathbf{x}^* = \underset{\mathbf{X}}{min}||Y - \mathbf{X}||^2$$

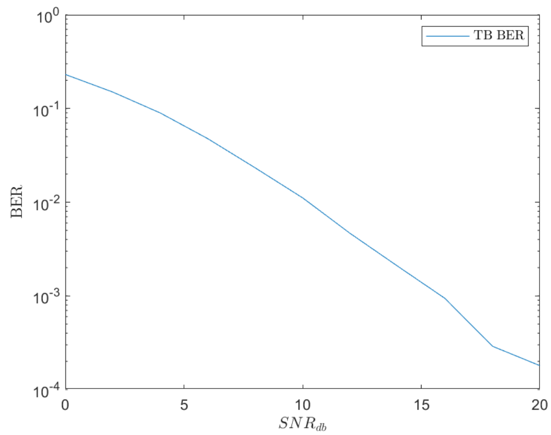

Figure 3: TB method: BER for $SNR_{db} = [0:2:20]$

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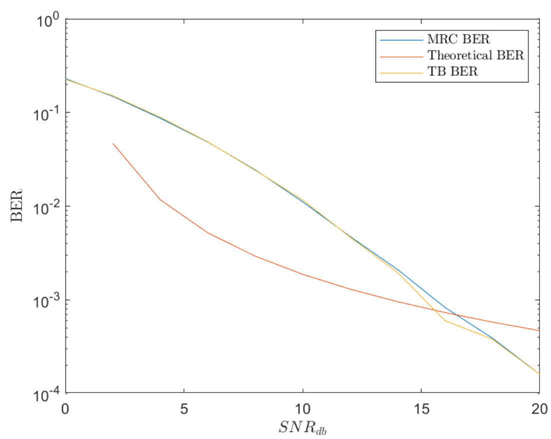

Figure 4: MRC-TB-Theoretical: BER for $SNR_{db} = [0:2:20]$

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Part 2 **1**

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