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```
% Reference Book David Tse and Pramod Viswanath(2005)
% Page 226, Figure 5.17

clc;
close all;
clear all;
% 4 Transmitters and 4 Receivers
Tx = 4;
Rx = 4;
% Symbol Periods
L = 4;
% Signal to Noise Ratio
SNR = [-10:20];
snr = 10.^(SNR/10);
```

1. SIMO(1 Transmitter and 4 Receivers)

```
Capacity_SIMO = zeros(1,length(snr));
% Loop to run till the total symbol periods
for i = 1:L
% Channel Matrix
h_SIMO = (randn(Rx,1)+1j*randn(Rx,1))/sqrt(2);
% Loop to run for all SNR values
for K = 1:length(snr)
Capacity_SIMO(K) = Capacity_SIMO(K) + log2(1+
 snr(K)*(h_SIMO'*h_SIMO));
end
end
% Channel Capacity
Capacity_SIMO = Capacity_SIMO/L;
```

2. MISO(4 Transmitters and 1 Receiver) without knowledge of CSI

```
Capacity_MISO_without_CSI = zeros(1,length(snr));
% Loop to run till the total symbol periods
for ite = 1:L
% Channel Matrix
```

```
h_MISO = (randn(1,Tx)+1j*randn(1,Tx))/sqrt(2);
% Loop to run for all SNR values
for K = 1:length(snr)
Capacity_MISO_without_CSI(K) = Capacity_MISO_without_CSI(K) + log2(1+
 (snr(K)*(h_MISO*h_MISO'))/(Tx*Tx)); % For Nt=Tx i.e. 4
end
end
% Channel Capacity
Capacity_MISO_without_CSI = Capacity_MISO_without_CSI/L;
```

3. MISO(4 Transmitters and 1 Receiver) with knowledge of CSI

```
Capacity_MISO_with_CSI = zeros(1,length(snr));
% Loop to run till the total symbol periods
for ite = 1:L
% Channel Matrix
h_MISO = (randn(1,Tx)+1j*randn(1,Tx))/sqrt(2);
% Loop to run for all SNR values
for K = 1:length(snr)
Capacity_MISO_with_CSI(K) = Capacity_MISO_with_CSI(K) + log2(1+
 snr(K)*(h_MISO*h_MISO')/Tx);
end
end
% Channel Capacity
Capacity_MISO_with_CSI = Capacity_MISO_with_CSI/L;
```

4. MIMO(4 Transmitters and 4 Receivers) with Equal Power Distribution

```
Capacity_MIMO_norm4 = zeros(1,length(snr));
Capacity_MIMO_norm3 = zeros(1,length(snr));
Capacity_MIMO_norm2 = zeros(1,length(snr));
Capacity_MIMO_norm1 = zeros(1,length(snr));
% Loop to run till the total symbol periods
for ite = 1:L
% Channel Matrix
h_MIMO4 = (randn(Rx,Tx)+1j*randn(Rx,Tx))/sqrt(2);
h_MIMO3 = (randn(3,3)+1j*randn(3,3))/sqrt(2);
h_MIMO2 = (randn(2,2)+1j*randn(2,2))/sqrt(2);
h_MIMO1 = (randn(1,1)+1j*randn(1,1))/sqrt(2);
for K = 1:length(snr)
Capacity_MIMO_norm4(K) = Capacity_MIMO_norm4(K) +
 log2(det(eye(Rx)+snr(K)*(h_MIMO4)*(h_MIMO4)'/Tx));
Capacity_MIMO_norm3(K) = Capacity_MIMO_norm3(K) +
 log2(det(eye(3)+snr(K)*(h_MIMO3)*(h_MIMO3)'/3));
Capacity_MIMO_norm2(K) = Capacity_MIMO_norm2(K) +
 log2(det(eye(2)+snr(K)*(h_MIMO2)*(h_MIMO2)'/2));
Capacity_MIMO_norm1(K) = Capacity_MIMO_norm1(K) +
 log2(det(eye(1)+snr(K)*(h_MIMO1)*(h_MIMO1)'));
```

```
end
end
% Channel Capacity
Capacity_MIMO_norm4 = Capacity_MIMO_norm4/L;
Capacity_MIMO_norm3 = Capacity_MIMO_norm3/L;
Capacity_MIMO_norm2 = Capacity_MIMO_norm2/L;
Capacity_MIMO_norm1 = Capacity_MIMO_norm1/L;
```

5. MIMO(4 Transmitters and 4 Receivers) with Water Filling Algorithm

Reference Book Andrea Goldsmith(2005), Page 327

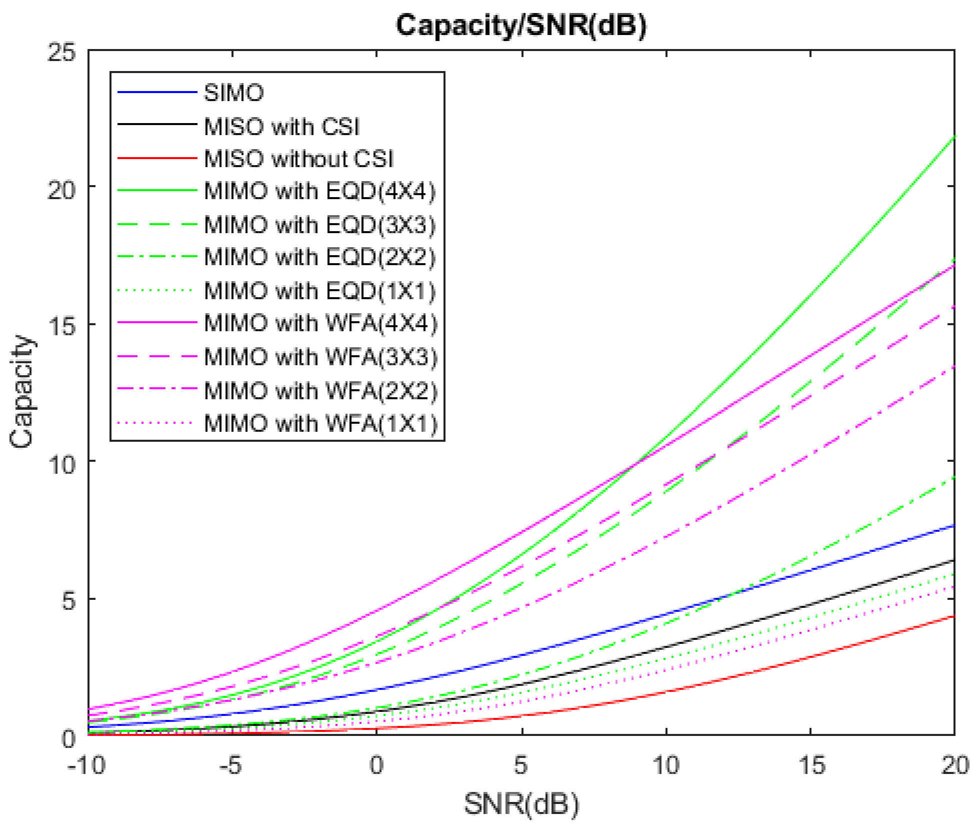
```
Capacity_MIMO_WFA4 = zeros(1,length(snr));
Capacity_MIMO_WFA3 = zeros(1,length(snr));
Capacity_MIMO_WFA2 = zeros(1,length(snr));
Capacity_MIMO_WFA1 = zeros(1,length(snr));
% Loop to run till the total symbol periods
for ite = 1:L
% Channel Matrix
h_MIMO4 = (randn(Rx,Tx)+1j*randn(Rx,Tx))/sqrt(2);
h_MIMO3 = (randn(3,3)+1j*randn(1,1))/sqrt(2);
h_MIMO2 = (randn(2,2)+1j*randn(1,1))/sqrt(2);
h_MIMO1 = (randn(1,1)+1j*randn(1,1))/sqrt(2);
% SVD of the channel matrix 'h_MIMO'
[u4,E4,v4]=svd(h_MIMO4);
[u3,E3,v3]=svd(h_MIMO3);
[u2,E2,v2]=svd(h_MIMO2);
[u1,E1,v1]=svd(h_MIMO1);
%Gamma calculation for optimal power allocation
e4=diag(E4);
e3=diag(E3);
e2=diag(E2);
e1=diag(E1);
y4=sort(e4.*e4);
y3=sort(e3.*e3);
y2=sort(e2.*e2);
y1=sort(e1.*e1);
% 4X4
if (4/(1+(1/y4(1)+1/y4(2)+1/y4(3)+1/y4(4))))<y4(1)
yo4=4/(1+(1/y4(1)+1/y4(2)+1/y4(3)+1/y4(4)));
elseif (3/(1+(1/y4(2)+1/y4(3)+1/y4(4))))<y4(2)
yo4=3/(1+(1/y4(2)+1/y4(3)+1/y4(4)));
elseif (2/(1+(1/y4(3)+1/y4(4))))<y4(3)
yo4=2/(1+(1/y4(3)+1/y4(4)));
else
yo4=4/(1+(1/y4(4)));
end
% 3X3
if (3/(1+(1/y3(1)+1/y3(2)+1/y3(3))))<y3(1)
yo3=3/(1+(1/y3(1)+1/y3(2)+1/y3(3)));
elseif (3/(1+(1/y3(2)+1/y3(3))))<y3(2)
```

```
yo3=3/(1+(1/y3(2)+1/y3(3)));
else
yo3=1/(1+(1/y3(3)));
end
% 2X2
if (2/(1+(1/y2(1)+1/y2(2))))<y2(1)
yo2=2/(1+(1/y2(1)+1/y2(2)));
else
yo2=1/(1+(1/y2(2)));
end
% 1X1
yo1=4/(1+(1/y1(1)));
% Loop to run for all SNR values
for K = 1:length(snr)
Capacity_MIMO_WFA4(K) = Capacity_MIMO_WFA4(K) + log2(1+(snr(K)*y4(3))/
yo4)+log2(1+(snr(K)*y4(4))/yo4);
Capacity_MIMO_WFA3(K) = Capacity_MIMO_WFA3(K) + log2(1+(snr(K)*y3(2))/
yo3)+log2(1+(snr(K)*y3(3))/yo3);
Capacity_MIMO_WFA2(K) = Capacity_MIMO_WFA2(K) + log2(1+(snr(K)*y2(1))/
yo2)+log2(1+(snr(K)*y2(2))/yo2);
Capacity_MIMO_WFA1(K) = Capacity_MIMO_WFA1(K) + log2(1+(snr(K)*y1(1))/
yo1);
end
end
% Channel Capacity
Capacity_MIMO_WFA4 = Capacity_MIMO_WFA4/L;
Capacity_MIMO_WFA3 = Capacity_MIMO_WFA3/L;
Capacity_MIMO_WFA2 = Capacity_MIMO_WFA2/L;
Capacity_MIMO_WFA1 = Capacity_MIMO_WFA1/L;
```

Plot of various Systems

```
figure
% Ploting SIMO capacity
plot(SNR,Capacity_SIMO,'b')
hold on
% Ploting MISO capacity with CSI Information
plot(SNR,Capacity_MISO_with_CSI,'k')
hold on
% Ploting MISO capacity without CSI Information
plot(SNR,Capacity_MISO_without_CSI,'r')
hold on
% Ploting MIMO capacity Equal Power Allocation(4Tx - 4Rx)
plot(SNR,real(Capacity_MIMO_norm4),'g-')
hold on
% Ploting MIMO capacity Equal Power Allocation(3Tx - 3Rx)
plot(SNR,real(Capacity_MIMO_norm3),'g--')
hold on
% Ploting MIMO capacity Equal Power Allocation(2Tx - 2Rx)
plot(SNR,real(Capacity_MIMO_norm2),'g-.')
hold on
% Ploting MIMO capacity Equal Power Allocation(1Tx - 1Rx)
plot(SNR,real(Capacity_MIMO_norm1),'g:')
```

```
hold on
% Ploting MIMO capacity with Water Filling Algorithm(4Tx - 4Rx)
plot(SNR,Capacity_MIMO_WFA4,'m-')
hold on
% Ploting MIMO capacity with Water Filling Algorithm(3Tx - 3Rx)
plot(SNR,Capacity_MIMO_WFA3,'m--')
hold on
% Ploting MIMO capacity with Water Filling Algorithm(2Tx - 2Rx)
plot(SNR,Capacity_MIMO_WFA2,'m-.')
hold on
% Ploting MIMO capacity with Water Filling Algorithm(1Tx - 1Rx)
plot(SNR,Capacity_MIMO_WFA1,'m:')
xlabel('SNR(dB)')
ylabel('Capacity')
title('Capacity/SNR(dB)')
legend('SIMO','MISO with CSI','MISO without CSI','MIMO with
 EQD(4X4)','MIMO with EQD(3X3)','MIMO with EQD(2X2)','MIMO with
 EQD(1X1)','MIMO with WFA(4X4)','MIMO with WFA(3X3)','MIMO with
 WFA(2X2)','MIMO with WFA(1X1)','Location','northwest');
```



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From the above graphical analysis, it can be concluded that:

- SIMO has better capacity performance than MISO system.
- MISO with CSI at transmitter shows a slightly better performance when compared with MISO system that do not have CSI.
- MIMO system has higher capacity than both SIMO and MISO.
- MIMO system with water filling algorithm has higher capacity at low SNR values as opposed to MIMO system with equal power distribution. However, the graph gets reversed with high values of SNR showing better performance when equal power distribution is used.
- Several plots have been shown of Water Filling Algorithm and Equal Power Distribution for various transmitters and receivers. As per the plot, the capacity reduces as the transmitters and receivers are reduced and becomes approximately equal to SISO when Tx=Rx=1. The same can be verified theoretically.