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QUESTION

Simulation of capacity of Rayleigh fading channel vs average SNR for the following cases

1. CSI is known at both transmitter and Receiver
2. CSI is known at the Receiver only.
3. Channel inversion power control is used.
4. Maximum Outage Capacity
5. AWGN Channel capacity with Same Average SNR as the RayLeigh channel. Simulate for average transmit SNR, $\gamma = \frac{P}{\sigma_n^2}$ in the range 0 - 30dB in steps of 5 dB and generate 10,000 channel realizations for each value of SNR To generate a Rayleigh fading channel vector of length N, use the following Matlab code: $h = \frac{1}{\sqrt{2}}(randn(1;N) + i \times randn(1;N))$

ABSTRACT

This report describes the simulation of Rayleigh Fading Channel with comparison the Ergodic Capacity, Shannon AWGN Capacity, Channel Inversion and Maximum outage Capacity. It indicates that it is affected with the h which applied to all measures of Capacity Channels.

INTRODUCTION

This simulation report has been analyzed by Matlab and LaTex software to check the relationship among the Ergodic Capacity, Shannon AWGN Capacity, Channel Inversion and Maximum outage Capacity. However, as the SNR increased cause the power to increase and if it is reduced the power also decreases.

Part 1. The Shannon Formula For calculating Capacity of an AWGN Channel is given given below:

$$C = B \log_2(1 + \gamma)$$

The Maltlab Codes

```
>> SNRdB=0:0.5:40; %Range of SNRs to simulate

h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); % Rayleigh flat fading channel with 10,000 channel realizations
sigma_z=1; % Asume Noise power to be unity

SNR = 10.^(SNRdB/10); %SNRs in linear scale
P=(sigma_z^2)*SNR./(mean(abs(h).^2)); %Calculate  values of P

C_ergodicawgn = (log2(1+ mean(abs(h).^2).*P/(sigma_z^2))); %AWGN channel capacity (Bound)
plot(snrdB,C_ergodicawgn,'-'); hold on;
legend('AWGN channel capacity');
title('AWGN channel');
xlabel('SNR (dB)');ylabel('Capacity (bps/Hz)');
```

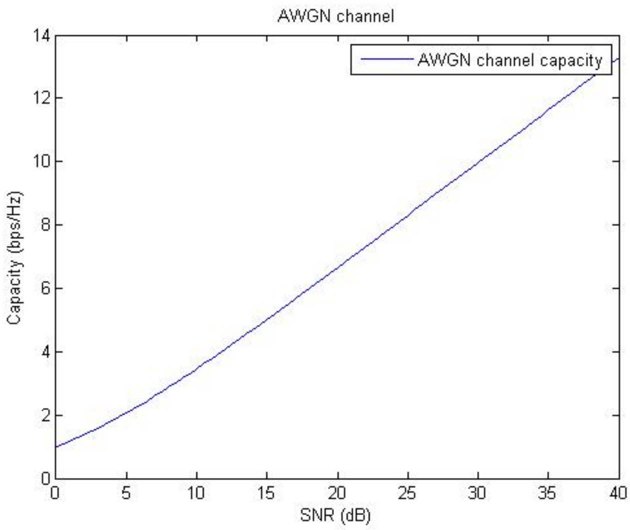
AWGN channel
AWGN channel capacity
Capacity (bps/Hz)
SNR (dB)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40

Figure 1:

Part 2. The Capacity of Ergodic Flat Fading channel, with channel state information CSI at receiver

$$C = \epsilon(B \log_2(1 + \frac{P(|h|)^2}{\delta^2}))$$

```
>> SNRdB=0:0.5:40; %Range of SNRs to simulate

h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); % Rayleigh flat fading channel with 10,000 channel realizations
sigma_z=1; % Asume Noise power to be unity

SNR = 10.^(SNRdB/10); %SNRs in linear scale
P=(sigma_z^2)*SNR./(mean(abs(h).^2)); %Calculate  values of P

C_erg = mean((log2(1+ ((abs(h).^2).')*P/(sigma_z^2)))); %CSI at Receiver Rx
plot(snrdB,C_erg,'red'); hold on;
legend('Capacity ergodic');
title('Capacity ergodic channel');
xlabel('SNR (dB)');ylabel('Capacity (bps/Hz)');
```

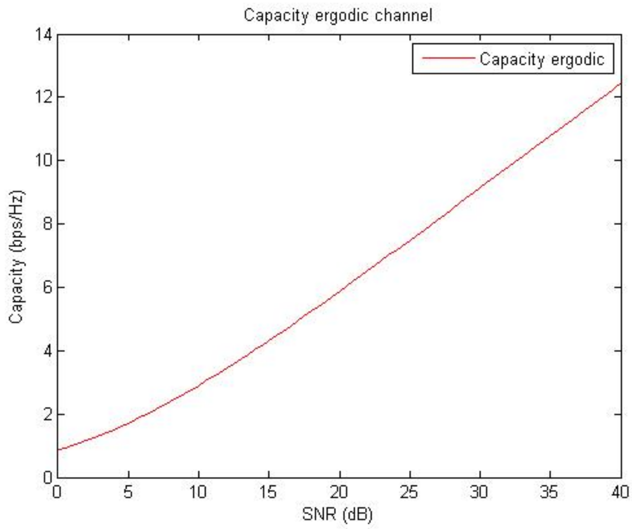

Figure 2:

Part 3. The Comparison between AWGN Channel vs Ergodic Flat Fading channel, with channel state information CSI at receiver

Comparison between

$C = B\log_2(1+\gamma)$ vs $C = \epsilon(B\log_2(1+\frac{P(|h|)^2}{\delta^2}))$

```
>> SNRdB=0:0.5:40; %Range of SNRs to simulate
h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); % Rayleigh flat fading channel with 10,000 channel realizations
sigma_z=1; % Asume Noise power to be unity
SNR = 10.^(SNRdB/10); %SNRs in linear scale
P=(sigma_z^2)*SNR./(mean(abs(h).^2)); %Calculate  values of P
C_erg_awgn = (log2(1+ mean(abs(h).^2).*P/(sigma_z^2))); %AWGN channel capacity (Bound)
C_erg = mean((log2(1+ ((abs(h).^2).')*P/(sigma_z^2)))); %Ergodic CSI at RX
plot(snrdB,C_erg_awgn,'blue'); hold on;
plot(snrdB,C_erg_awgn,'red');
plot(snrdB,C_erg,'Blue');
legend('AWGN channel capacity','CSI at RX');
title('Comparison between Capacity AWGN Channel vs Ergodic CSI at Rx');
xlabel('SNR (dB)');ylabel('Capacity (bps/Hz)');
```

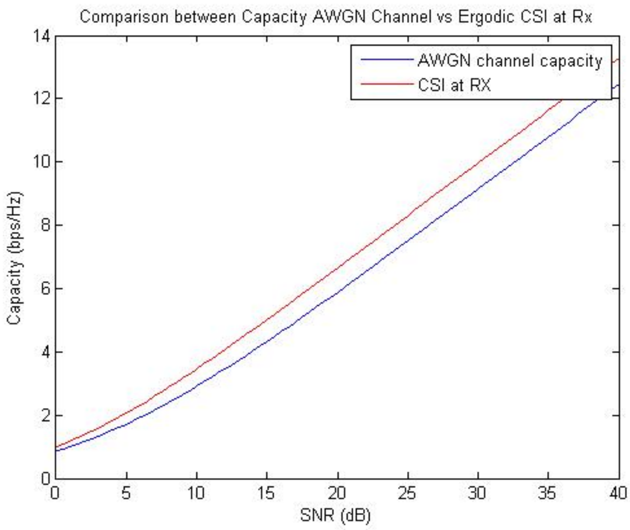

Figure 3:

We see that the Shannon capacity of a fading channel with receiver CSI only is less than the Shannon capacity of an AWGN channel with the same average SNR. In other words, fading reduces Shannon capacity when only the receiver has CSI. But it can also be observed that there is a much lower performance difference between the capacities of AWGN and Rayleigh channels then one would expect. This is highly indicative that the coding of fading channels will yield considerable coding gain for large SNR.

Part 4. The Channel Inversion Capacity

$$C = B\log_2(1 + \frac{1}{E(\frac{\delta^2}{P|h|^2})})$$

```
>> SNRdB=0:0.5:40; %Range of SNRs to simulate
h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); % Rayleigh flat fading channel with 10,000 channel realizations
sigma_z=1; % Asume Noise power to be unity
SNR = 10.^(SNRdB/10); %SNRs in linear scale
P=(sigma_z^2)*SNR./(mean(abs(h).^2)); %Calculate  values of P

C_inv = log2(1+ 1./((sigma_z^2)./mean(abs(h).^2).*P)); %channel inversion

plot(snrdB,C_inv,'blue'); hold on;
legend('Channel Inversion');
title('Channel Inversion ');
xlabel('SNR (dB)');ylabel('Capacity (bps/Hz)');
```

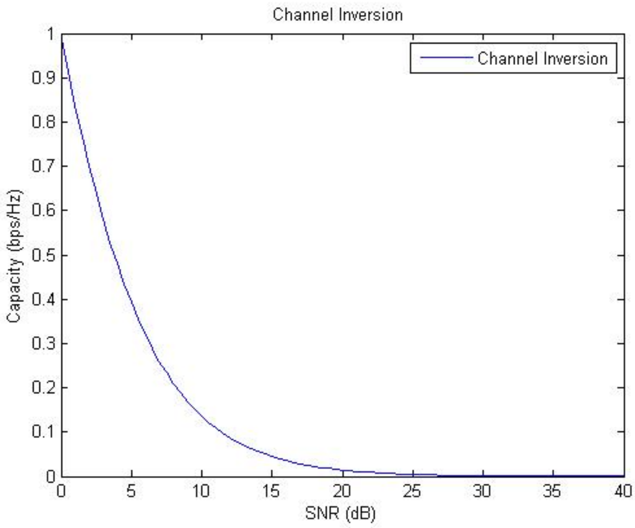

Figure 4:

Part 5. The Maximum Outage Capacity

$$C = B \log_2(1 + \frac{1}{E(\frac{\delta^2}{P|h|^2})})$$

```
>> SNRdB=0:0.5:40; %Range of SNRs to simulate
h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); % Rayleigh flat fading channel with 10,000 channel realizations
sigma_z=1; % Asume Noise power to be unity
SNR = 10.^(SNRdB/10); %SNRs in linear scale
P=(sigma_z^2)*SNR./(mean(abs(h).^2)); %Calculate  values of P

P_out=40e-2;
C_out = (1-P_out).*log2(1+ mean(abs(h).^2).*P/(sigma_z^2)); %Maximum Outage Capacity

plot(SNRdB,C_out,'black'); hold on;
legend('Max Capacity with Outage');
title('Maximum Outage Capacity ');
xlabel('SNR (dB)');ylabel('Capacity (bps/Hz)');
```

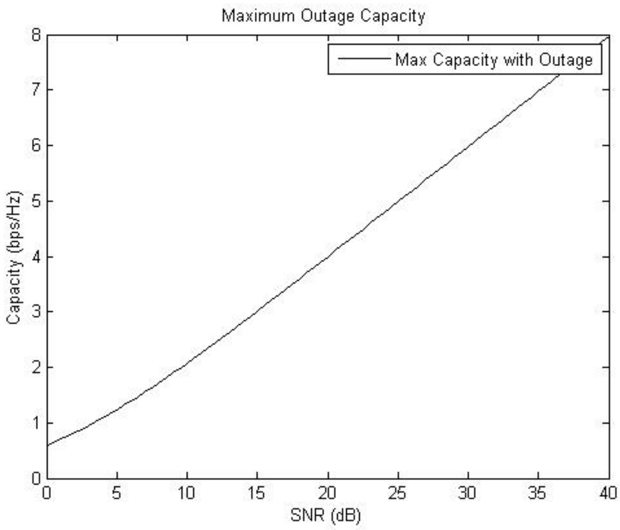

Figure 5:

Part 6. The Capacity Comparison of all Channels

```
>> SNR_dB=0:0.5:40; %Simulation of rayleigh Fading Channel vs The Average SNR

h= (randn(1,10000) + 1i*randn(1,10000) )/sqrt(2); %Rayleigh flat channel with 10,000 channel realizations for each value of SNR
sgm_y=1; %Assume Noise power is unity

SNR = 10.^(SNR_dB/10); %SNRs in linear
P=(sgm_y^2)*SNR./(mean(abs(h).^2)); %Calculate P values

C_ERG_AWGN = (log2(1+ mean(abs(h).^2).*P/(sgm_y^2))); %AWGN channel capacity (Bound)
C_Ergodic = mean((log2(1+ ((abs(h).^2).')*P/(sgm_y^2)))); %CSI at RX
C_inversion = log2(1+ 1./((sgm_y^2)./mean(abs(h).^2).*P)); %channel inversion
P_outage=40e-2;
C_outage = (1-P_outage).*log2(1+ mean(abs(h).^2).*P/(sgm_y^2)); %Capacity with Outage

plot(SNR_dB,C_ERG_AWGN,'-'); hold on;
plot(SNR_dB,C_Ergodic,'red');
plot(SNR_dB,C_inversion,'blue');
plot(SNR_dB,C_outage,'black');
legend('AWGN channel capacity','CSI at Receiver','Channel Inversion','Capacity with Outage');
title('Fading channel - Ergodic capacity');
xlabel('SNR_dB (dB)');ylabel('Capacity (bps/Hz)');
```

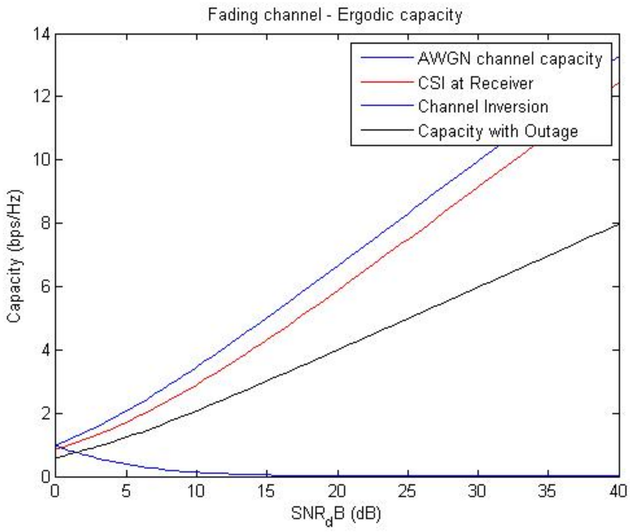

Figure 6:

Conclusion

Based on simulation the capacity of a Rayleigh flat fading channel versus SNR on the given cases of Channel State Information (CSI) above, we have studied that the AWGN Channel provide better performance compared to other shown channels which seem to have low power average.