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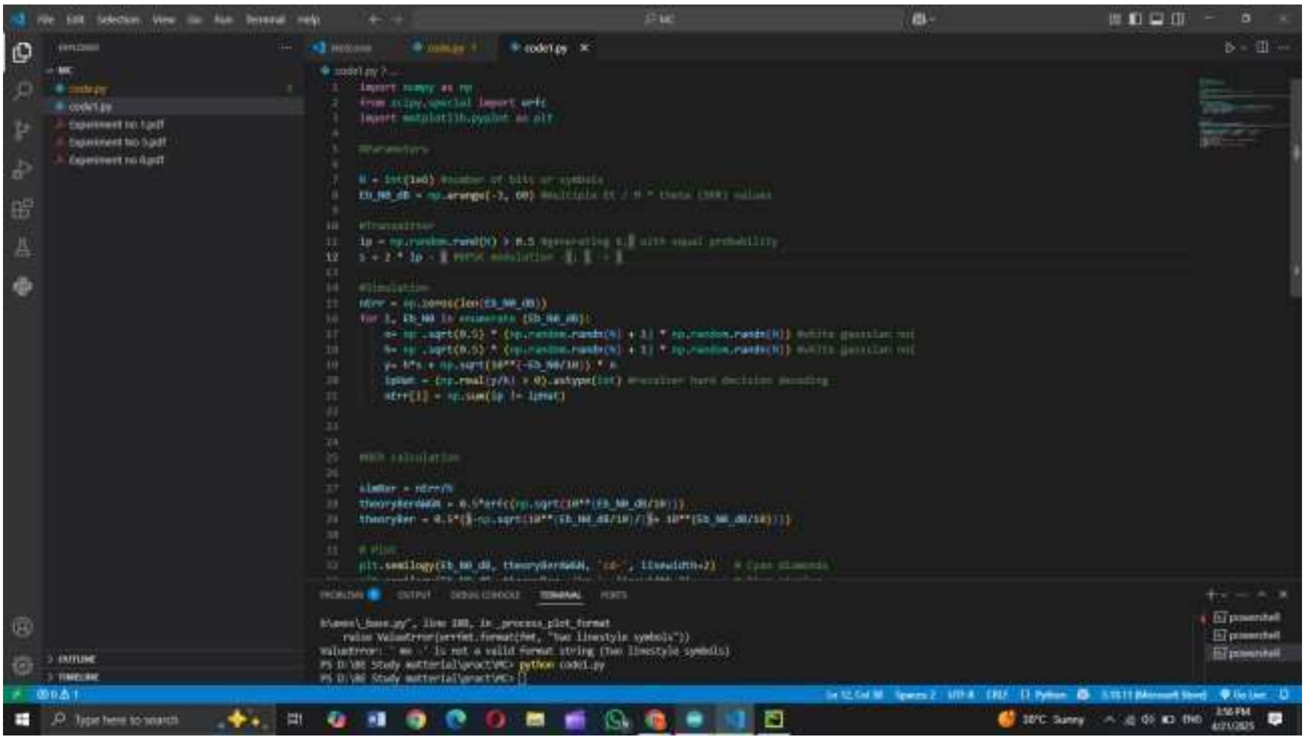
**Experiment no: 4**

```
import numpy as np
from scipy.special import erfc
import matplotlib.pyplot as plt

#Parameters

N = int(1e6) #number of bits or symbols
Eb_N0_dB = np.arange(-3, 60) #multiple Et / M * theta (SNR) values

#Transmitter
ip = np.random.rand(N) > 0.5 #generating 0,1 with equal probability
s = 2 * ip - 1 #BPSK modulation -1; 1 -> 1

#Simulation
nErr = np.zeros(len(Eb_N0_dB))
for i, Eb_N0 in enumerate (Eb_N0_dB):
    n= np .sqrt(0.5) * (np.random.randn(N) + 1j * np.random.randn(N)) #white
gaussian noi
    h= np .sqrt(0.5) * (np.random.randn(N) + 1j * np.random.randn(N)) #white
gaussian noi
    y= h*s + np.sqrt(10**(-Eb_N0/10)) * n
    ipHat = (np.real(y/h) > 0).astype(int) #receiver hard decision decoding
    nErr[i] = np.sum(ip != ipHat)


#BER calculation

simBer = nErr/N
theoryBerAWGN = 0.5*erfc(np.sqrt(10**(Eb_N0_dB/10)))
theoryBer = 0.5*(1-np.sqrt(10**(Eb_N0_dB/10)/(1+ 10**(Eb_N0_dB/10))))

# Plot
plt.semilogy(Eb_N0_dB, theoryBerAWGN, 'cd-', linewidth=2)   # Cyan diamonds
plt.semilogy(Eb_N0_dB, theoryBer, 'bp-', linewidth=2)       # Blue circles
plt.semilogy(Eb_N0_dB, simBer, 'mx-', linewidth=2)          # Magenta Xs

plt.axis([-3, 35, 1e-5, 0.5])
plt.grid(True, which="both")
plt.legend(['AWGN-Theory', 'Rayleigh-Theory', 'Rayleigh-Simulation'])
plt.xlabel('Eb/No, dB')
plt.ylabel('Bit Error Rate')
plt.title('BER for BPSK modulation in Rayleigh channel')
plt.show()
```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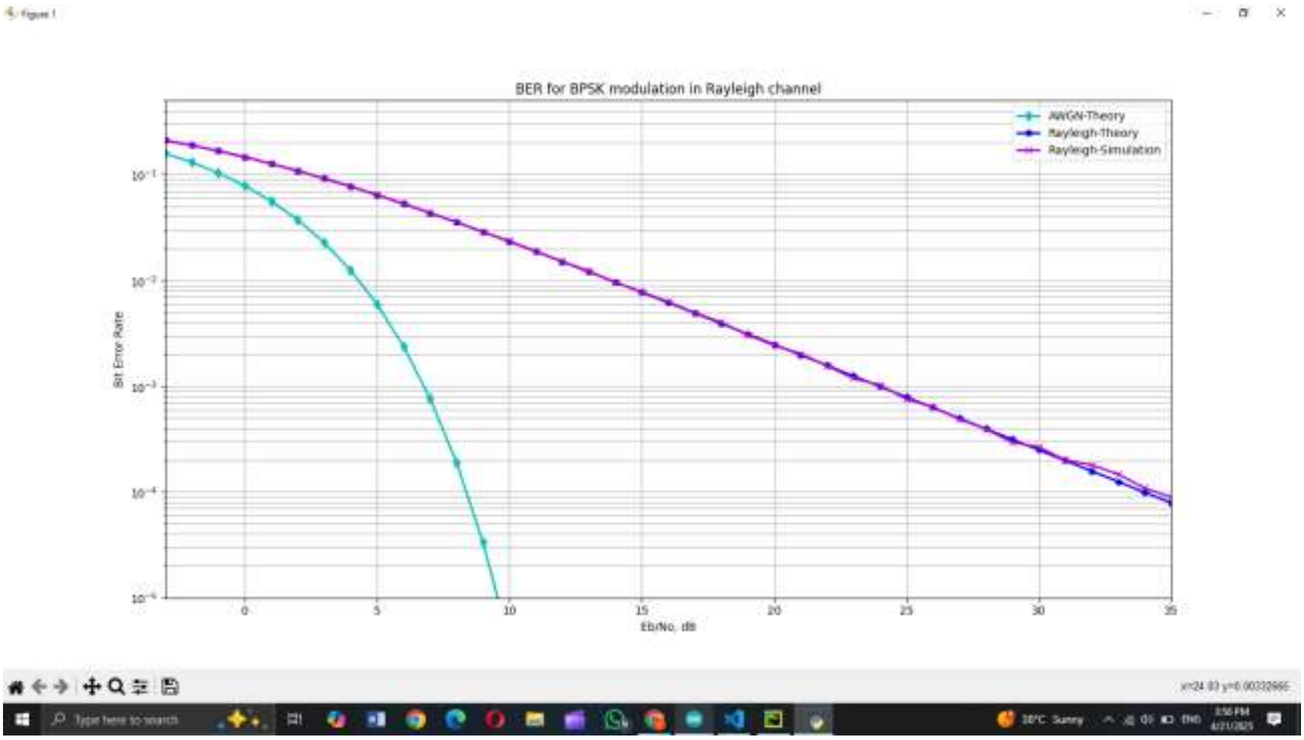
BER for BPSK modulation in Rayleigh channel
AWGN-Theory
Rayleigh-Theory
Rayleigh-Simulation
Bit Error Rate
Eb/No, dB