LAB1 Report

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My results for d = [50:50:600]

Run LAB1_111550016.m, and the results will be displayed in the command window. However, note that the results will output d=50~600 (every 50) first, and then output the results of Constellation Diagrams for 600, 400, 200, and 100.

For d = [50:50:600], just look at the first part of output(d=50~600 (every 50)).

```
>> LAB1_111550016
-----------------------------------------------------------------------------------------------
Link distance (d) = 50 meters
Received power (Prx) = 3.958e-10 (Watts) = -64.03 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 3.96e+02 = 2.60e+01 (dB)
Theoretical SNR = 3.96e+02 = 2.60e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0000, 16QAM = 0.0000, 64QAM = 0.0000
Theoretical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.25e+06, 64QAM = 1.83e+06
Empirical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.25e+06, 64QAM = 1.82e+06
optimal modulation scheme for link distance d: 64-QAM
-----------------------------------------------------------------------------------------------
Link distance (d) = 100 meters
Received power (Prx) = 9.895e-11 (Watts) = -70.05 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 9.89e+01 = 2.00e+01 (dB)
Theoretical SNR = 9.89e+01 = 2.00e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0000, 16QAM = 0.0000, 64QAM = 0.0137
Theoretical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.23e+06, 64QAM = 1.69e-18
Empirical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.23e+06, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: 16-QAM
-----------------------------------------------------------------------------------------------
Link distance (d) = 150 meters
Received power (Prx) = 4.398e-11 (Watts) = -73.57 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 4.40e+01 = 1.64e+01 (dB)
Theoretical SNR = 4.40e+01 = 1.64e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0000, 16QAM = 0.0014, 64QAM = 0.0673
Theoretical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 4.08e+03, 64QAM = 1.87e-115
Empirical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.67e+04, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: QPSK
-----------------------------------------------------------------------------------------------
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--------------------------------------------------------------------------------------------
Link distance (d) = 200 meters
Received power (Prx) = 2.474e-11 (Watts) = -76.07 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 2.47e+01 = 1.39e+01 (dB)
Theoretical SNR = 2.47e+01 = 1.39e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0000, 16QAM = 0.0132, 64QAM = 0.1272
Theoretical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 1.09e-17, 64QAM = 7.23e-231
Empirical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 6.25e+05, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------------------
Link distance (d) = 250 meters
Received power (Prx) = 1.583e-11 (Watts) = -78.00 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 1.58e+01 = 1.20e+01 (dB)
Theoretical SNR = 1.58e+01 = 1.20e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0000, 16QAM = 0.0377, 64QAM = 0.1761
Theoretical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 5.40e+05, 16QAM = 2.65e-61, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 3.12e+05, QPSK = 5.33e+05, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------------------
Link distance (d) = 300 meters
Received power (Prx) = 1.099e-11 (Watts) = -79.59 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 1.10e+01 = 1.04e+01 (dB)
Theoretical SNR = 1.10e+01 = 1.04e+01 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0005, 16QAM = 0.0691, 64QAM = 0.2134
Theoretical Throughput (bit/s): BPSK = 3.04e+05, QPSK = 1.02e+05, 16QAM = 4.43e-119, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 3.04e+05, QPSK = 1.00e+05, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------------------

--------------------------------------------------------------------------------------------
Link distance (d) = 350 meters
Received power (Prx) = 8.077e-12 (Watts) = -80.93 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 8.08e+00 = 9.07e+00 (dB)
Theoretical SNR = 8.08e+00 = 9.07e+00 (dB)
Empirical BER: BPSK = 0.0000, QPSK = 0.0022, 16QAM = 0.1023, 64QAM = 0.2402
Theoretical Throughput (bit/s): BPSK = 2.73e+05, QPSK = 1.08e+02, 16QAM = 3.61e-182, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 2.71e+05, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------------------
Link distance (d) = 400 meters
Received power (Prx) = 6.184e-12 (Watts) = -82.09 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 6.18e+00 = 7.91e+00 (dB)
Theoretical SNR = 6.18e+00 = 7.91e+00 (dB)
Empirical BER: BPSK = 0.0003, QPSK = 0.0063, 16QAM = 0.1331, 64QAM = 0.2610
Theoretical Throughput (bit/s): BPSK = 1.03e+05, QPSK = 5.51e-06, 16QAM = 7.46e-243, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 1.21e+05, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------------------
Link distance (d) = 450 meters
Received power (Prx) = 4.886e-12 (Watts) = -83.11 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 4.89e+00 = 6.89e+00 (dB)
Theoretical SNR = 4.89e+00 = 6.89e+00 (dB)
Empirical BER: BPSK = 0.0010, QPSK = 0.0136, 16QAM = 0.1610, 64QAM = 0.2787
Theoretical Throughput (bit/s): BPSK = 6.70e+03, QPSK = 8.78e-19, 16QAM = 1.56e-299, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 4.17e+03, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
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Link distance (d) = 500 meters
Received power (Prx) = 3.958e-12 (Watts) = -84.03 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 3.96e+00 = 5.97e+00 (dB)
Theoretical SNR = 3.96e+00 = 5.97e+00 (dB)
Empirical BER: BPSK = 0.0026, QPSK = 0.0230, 16QAM = 0.1861, 64QAM = 0.2932
Theoretical Throughput (bit/s): BPSK = 1.13e+01, QPSK = 2.30e-35, 16QAM = 0.00e+00, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 0.00e+00, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 550 meters
Received power (Prx) = 3.271e-12 (Watts) = -84.85 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 3.27e+00 = 5.15e+00 (dB)
Theoretical SNR = 3.27e+00 = 5.15e+00 (dB)
Empirical BER: BPSK = 0.0054, QPSK = 0.0347, 16QAM = 0.2076, 64QAM = 0.3051
Theoretical Throughput (bit/s): BPSK = 1.18e-04, QPSK = 2.99e-56, 16QAM = 0.00e+00, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 0.00e+00, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 600 meters
Received power (Prx) = 2.749e-12 (Watts) = -85.61 (dBm)
Empirical average noise power = 9.99e-13 (watts) = -9.00e+01 (dBm)
Theoretical average noise power = 1.00e-12 (watts) = -9.00e+01 (dBm)
Empirical SNR = 2.75e+00 = 4.39e+00 (dB)
Theoretical SNR = 2.75e+00 = 4.39e+00 (dB)
Empirical BER: BPSK = 0.0098, QPSK = 0.0485, 16QAM = 0.2265, 64QAM = 0.3152
Theoretical Throughput (bit/s): BPSK = 2.90e-12, QPSK = 3.15e-81, 16QAM = 0.00e+00, 64QAM = 0.00e+00
Empirical Throughput (bit/s): BPSK = 0.00e+00, QPSK = 0.00e+00, 16QAM = 0.00e+00, 64QAM = 0.00e+00
optimal modulation scheme for link distance d: BPSK
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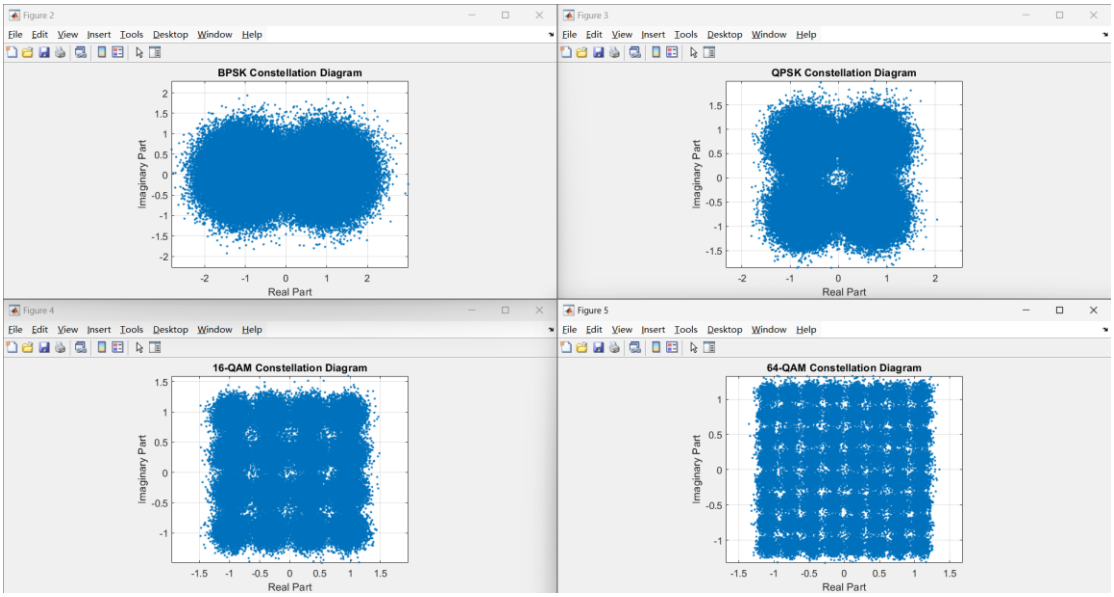

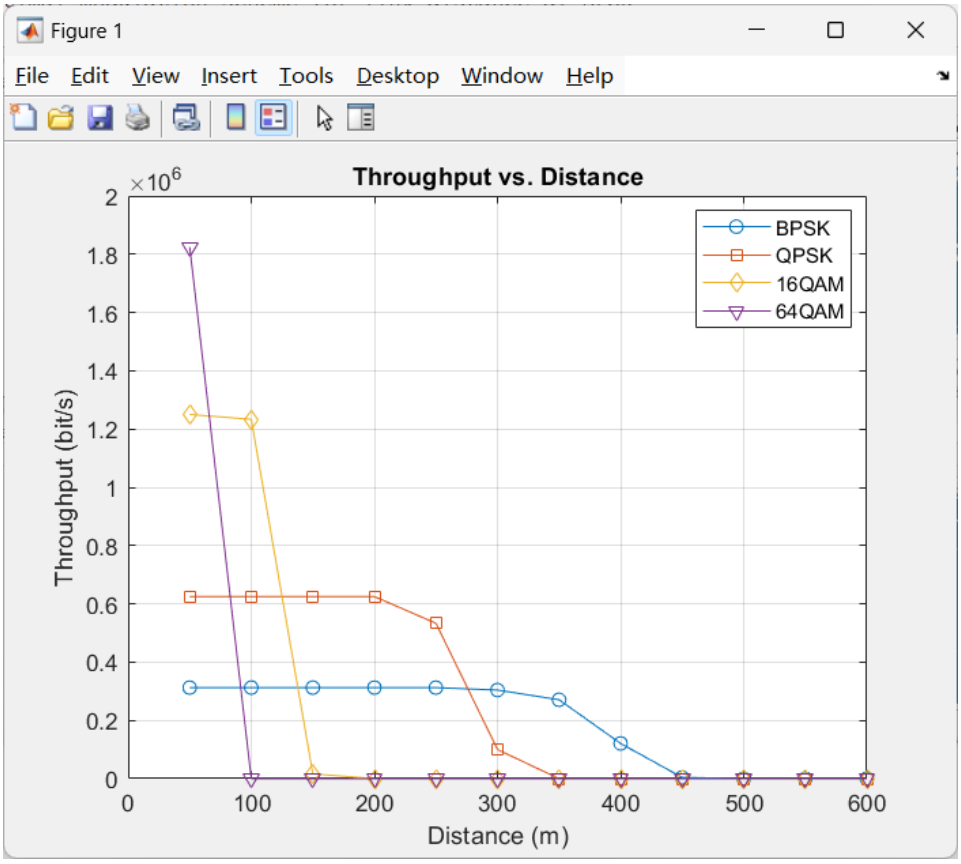
Figure 1
File Edit View Insert Tools Desktop Window Help
Throughput vs. Distance
×10^6
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Throughput (bit/s)
0
100
200
300
400
500
600
Distance (m)
BPSK
QPSK
16QAM
64QAM

Assume there exists a theoretical modulation table given in SNR_BER.mat

Run report_question_111550016.m, and modify the 'packet_len_bit' in line 276 to 100, 2000, 4000 to test all results.

Packet size = 100 bits

```
--------------------------------------------------------------------------------
Link distance (d) = 50 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: 64-QAM
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 100 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: 16-QAM
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 150 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: 16-QAM
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 200 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 250 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 300 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 350 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 400 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 450 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: QPSK


--------------------------------------------------------------------------------
Link distance (d) = 500 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------
Link distance (d) = 550 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------
Link distance (d) = 600 meters, Packet size = 12.5(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
```

Packet size = 2000 bits

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--------------------------------------------------------------------------------
Link distance (d) = 50 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: 64-QAM
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 100 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: 16-QAM
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 150 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 200 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 250 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 300 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: QPSK
--------------------------------------------------------------------------------
Link distance (d) = 350 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------
Link distance (d) = 400 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
--------------------------------------------------------------------------------
Link distance (d) = 450 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
```

```
Link distance (d) = 500 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 550 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 600 meters, Packet size = 250(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
```

Packet size = 4000 bits

```
-------------------------------------------------------------------------------------------------
Link distance (d) = 50 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: 64-QAM
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 100 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: 16-QAM
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 150 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 200 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 250 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: QPSK
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 300 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: QPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 350 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 400 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 450 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK


-------------------------------------------------------------------------------------------------
Link distance (d) = 500 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 550 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
-------------------------------------------------------------------------------------------------
Link distance (d) = 600 meters, Packet size = 500(bytes)
empirical modulation scheme for link distance d: BPSK
theoretical modulation scheme for link distance d: BPSK
```

Note: The empirical modulation scheme involves inputting d and l into previously computed LAB data, the theoretical modulation scheme calculates using data from SNR_BER.mat.

Compare: For the theoretical modulation scheme, QPSK is used when the distance is smaller, and BPSK is used when it is larger, although 16-QAM and 64-QAM were not utilized in the testing. The theoretical modulation scheme closely aligns with the empirical modulation scheme when the distance is larger.

What have you learned from this lab?
Ans: I have learned a lot from this LAB session and clarified many concepts that I previously didn't understand, such as the usage of dBm, watts, and dB, and also learned many MATLAB techniques.

What difficulty have you met in this lab?
Ans: Basically, each task is a big problem. Not only does it require good mathematical skills, but also a complete understanding of communication principles. Moreover, there are many small details that need attention, making it really challenging.