**İSTANBUL MEDİPOL UNIVERSITY**



**EECD1212913: DIGITAL COMMUNICATION LABORATORY**

**Lab report No:.3: Digital modulation techniques**

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**Introduction**

The objective of this experiment is to understand the various digital modulation techniques and observe the related modulation quality measurements. To familiarize ourselves with the following items:

• Various modulation types.

• Constant envelope versus higher order modulations.

• Understanding power, spectral efficiency, and data rate trade-offs.

• Comparisons of various modulation types in terms of time envelope, spectral efficiency, EVM performance, constellation, and eye diagrams.

• The tradeoff between higher data rates and higher susceptibility to noise at higher orders of modulation (e.g., 64QAM). Investigation of overall capacity change (increase or decrease) at higher modulations.

• Understanding CCDF (Complementary Cumulative Distribution Function).

• Controlling SDR devices using MATLAB.

***PART I***

Object Initialization Settings for transmitter and receiver.

Table 1 Tx and RX Initialization Settings

|  |  |  |  |
| --- | --- | --- | --- |
| **SN** | **Parameter** | **Transmitter** | **Receiver** |
| 1 | Gain: | -10dB | 20dB |
| 2 | CenterFrequency: | 2.4GHz | 2.4GHz |
| 3 | BasebandSampleRate: | Samples/s | Samples/s |
| 4 | RadioID: *(found using findPlutoRadio command)* | sn:10447354119600060d001800cf281e583b | sn:104473dc599300131200210082672a4170 |
| 5 | Samples per frame |  | Samples |
| 6 | GainSource |  | Manual |
| 7 | OutputDataType |  | Double |
| 8 | Pre amble size: | 2^7 - 1 |  |
| 9 | Data sıze | 512 (QPSK symbols) |  |
|  | Roll-off factor | 0.5 |  |

Question 5

The received signal power is calculated to be 1.24e-10 W while the RMS value of EVM is 7.1343, the noise signal power is 1.60e-13

The plot of the power spectrum of received signal and the noise power from the above settings are as shown in figure 1. From the above calculated values the signal to noise ratio SNR = 1.24e-10/1.60e-13 =



Question 9

Different transmitter gains were used as shown in the table, the SNR increases with increasing signal to noise ratio, which reflects higher signal power compared to the noise in the AWGN channel.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| TX Gain | EVM | RX Power | Noise Power | SNR | SNR (dB) | EVM (SNR) |
| -10 | 7.13 | 1.24E-10 | 1.60E-13 | 7.75E+02 | 28.89 | 22.94 |
| -8 | 4.92 | 3.85E-10 | 1.81E-13 | 2.13E+03 | 33.28 | 22.9382 |
| -6 | 7.22 | 6.60E-10 | 2.27E-13 | 2.91E+03 | 34.64 | 26.1607 |
| -4 | 7.35 | 1.02E-09 | 1.99E-13 | 5.13E+03 | 37.10 | 22.8293 |
| -2 | 5.49 | 1.54E-09 | 2.20E-13 | 7.00E+03 | 38.45 | 22.6743 |
| 0 | 7.37 | 2.47E-09 | 2.09E-13 | 1.18E+04 | 40.73 | 25.2086 |

As observed from the table SNR increases with increasing TX power from -10 dB to 0 dB.

Question 10

From the obtained value of EVM we calculate the SNR value for -10dB, there is however a notable difference between SNR values calculated from received power and that obtained from EVM, this can be because the EVM is prone to errors especially when a symbol is associated with a wrong constellation point simply because it felt close to that region due to noise.

***PART II***

Question 2

The plots in figure shown below show power spectrum for symbols transmitted with modulations of 4QAM, 16QAM and 64QAM.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Figure 1 Pspectrum for 4QAM, 16QAM and 64QAM | | |

Plots show ***decreasing received power*** of the signal ***with increasing modulation***, this can be attributed to the increasing number of constellation points taking more power to transmit the same signal, and susceptibility to noise, hence, higher modulation orders require higher SNR for proper detection.

Question 3

The constellation diagrams for 4QAM, 16QAM and 64QAM are as displayed in figure 3

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Figure 2 Constellation Diagrams for 4QAM 16 QAM and 64QAM | | |

The constellation diagrams show that symbols from 4QAM are more dispersed from ideal point, same for 64QAM with 16QAM being the least dispersed. Since same transmit power was used, this can be caused by relative noise power present during respective transmissions as each modulation was transmitted at its own instant in time which may encounter different channel characteristics hence different noise levels.

The eye diagrams are as shown in figure 3

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Figure 3 Eye diagrams for 4QAM, 16QAM and 64QAM | | |

The eye diagrams for 4QAM and 16QAM are wide enough to suggest low susceptibility to noise, however optimal sampling points show the effect of noise and the possibility of sampling more than one point, hence making errors.

The levels of the eye ***on each of corresponding I and Q*** eye diagrams are 2 for 4QAM, 4 for 16QAM and 8 for 64 QAM, these corresponds to the number of constellation points.

The eyes are 1 eye for 4QAM, 3 eyes for 16QAM and 7 eyes for 64QAM.

Question 4

As modulation order increases, constellation points become dense and hence closely packed, this makes the received symbols prone to be associated with wrong constellation points when they are distorted by noise and other impairments. Thus, with higher modulation order it is more likely to make errors hence given the same noise level, impairments and transmit power, we expect the EVM to increase. However the impairments may change based on environment and thus EVM may not always increase based on increased modulation order especially if other factors become more prominent.

Question 5

The plots for 99% occupied bandwidth are as in figure 4, while increasing the modulation order means ***packing more constellation points in the same filter*** hence achieving higher data rates, ***the occupied bandwidth as determined by the filter*** is expected to be the same, the discrepancy between the figures can be attributed to equipment impairments.

|  |  |  |
| --- | --- | --- |
|  |  |  |
| 4QAM 99% OBW | 16QAM 99% OBW | 64QAM 99% OBW |

***PART III***

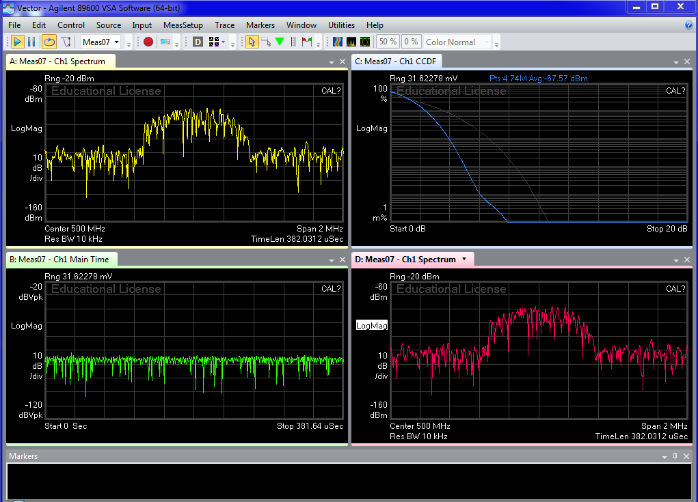
Question 1

The constellation diagram of QPSK shows zero crossings suggesting high dynamic ranges where OQPSK and π/4 QPSK Do not have zero crossings. However, it can be noticed that π/4 QPSK has higher power transitions which shows higher dynamic range as compared to OQPSK. This is also supported by CCDF diagrams. This also explains why the polar diagram for OQPSK shows a promising performance as compared to the others.

As for the PAPR, since OQPSK has lower dynamic ranges, we expect it to have the lowest PAPR compared to the others.

Question 2

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