

Molly Scarlet DSP and Comms Assignment

by Molly Scarlet

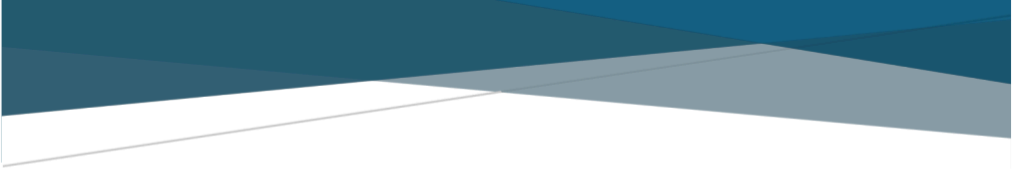
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ACDA6008 DIGITAL SIGNAL PROCESSING AND COMMUNICATIONS

Simulation of Digital Modulation Techniques



An overview of several digital modulation techniques including descriptions, overview, Simulink modelling and graphical displays of data obtained, concluding with an overview of what the data tells the reader regarding digital modulation schemes.

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Introduction

Digital signal processing and communications cover a very broad range of different techniques, theories and other information regarding the manipulation and analysis of digital signals. There is a hugely wide range of potential applications for digital signal processing from audio and sound processing, radar, image processing, etc [1].

Within this assignment a brief description of digital signal modulation will be given, and an overview of a number of digital signal modulation methods including their function and applications, as well as some basic modelling of each modulation scheme in order to show how each different type of modulation scheme response to different noise levels.

Overview

What is modulation?

Modulation is a process within primarily electronics and communications engineering that involves effectively taking a normal ^{Colloquialism} ~~bdg~~ waveform (known as the carrier signal) and combining it with a different signal that typically will contain a set of data to be transmitted (known as the modulation signal). The two signals are combined into one using a specific method known as a modulation scheme [2].

Modulation schemes use a variety of methods in order to combine the carrier and modulation signals. These methods have their own advantages and disadvantages based on how they operate, such as resistance to interference or processing speed, however the specific advantages and disadvantages for specific modulation schemes will be covered later.

Testing Methodology

For this assignment a number of tests had to be carried out on a variety of modulation schemes. The processes for these tests was the same for every single modulation scheme in order to ensure comparable results were obtained.

To begin with, a model of each modulation scheme was created using MATLAB Simulink. This included a modulation section and a demodulation section with an additive white gaussian noise (AWGN) noise channel between the two. This AWGN channel enables an accurate enough simulation of noise between the modulation and demodulation to simulate interference in a through-air transmission [3].

Additionally, a number of measuring tools such as scopes and most importantly an error rate calculation was placed onto the simulation. By attaching one terminal to the original signal and the other to the received demodulated signal, this will calculate the difference between the original and received signals providing a bit error rate (BER) value. The BER value is a value from 0 to 1 that indicates how

much of the received data matches the original data. By running the simulation at different noise values and comparing the average BER for each noise level we can compare the performance of each modulation scheme at different noise levels.

Whilst it would be possible to record and replay some data, a bernoulli binary generator was used. This MATLAB Simulink block will generate a random data stream every single time the simulation is run, allowing a repeatedly random set of data to work off of and whilst it will not be perfectly random due to how computer-based random generators work, it will provide a sufficient level of randomisation in order to evaluate the results.

Amplitude Shift Keying (ASK) Modulation

Overview and Background

Amplitude Shift Keying (ASK) modulation operates on the principle of adjusting the amplitude of the carrier signal based on the data encoded within the modulation signal. The modulator will vary the amplitude of the carrier signal to an alternative value to represent a 1 or a 0, for example a 1 may be represented with full amplitude whilst a 0 may be represented by half-amplitude.

ASK is a particularly simple and basic modulation scheme yet it is fairly effective in its modulation. This makes it relatively easy to implement, added onto by its low implementation cost. Unfortunately however, ASK is more susceptible to noise compared to a number of other modulation schemes. A worse signal to noise ratio (SNR) can affect ASK modulation significantly. Additionally, ASK modulation is fairly limited in terms of data rate. Due to the nature of ASK modulation, it is not particularly data efficient, and it cannot achieve a particularly high data rate [4].

Due to this, ASK modulation is popular for a number of more cost-sensitive systems that do not require a higher data rate, such as radio-frequency identification (RFID) systems and short distance medical system remote monitoring [5].

Simulink Modelling

Shown in Figure 3 below is the MATLAB Simulink model of PSK used to generate the results on how the modulation scheme handles noise. It consists of a modulation section, an AWGN channel to simulate interference, a demodulation section, and a bit error rate calculation. Within the ASK model, a time delay was also used in order to properly calibrate the transmitted and received signals for the bit error rate calculation.

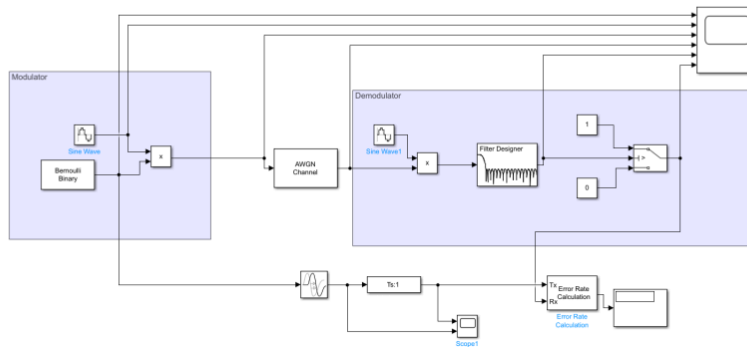


Figure 1 Simulink Model of ASK

Simulation Results

A series of tests were performed on the model, calculating the bit error rate (BER) at different noise levels on the AWGN. 10 different BER values were calculated for each noise level, demonstrating noise levels where the modulation scheme had no errors whatsoever to the point at which the BER reached of approximately 0.5. A BER of approximately 0.5 is considered a critical failure because at this point, the simulation is getting the correct values 50% of the time which is the same as just guessing one way or another.

Average BER values were then calculated for each signal-to-noise ratio (SNR) value as well as standard deviations of the data. This allowed the creation of the **table and graph seen below** which demonstrates the point at which the modulation scheme suffered what level of failure due to the noise levels.

SNR	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Average	Standard Deviation
5	0	0	0	0	0	0	0	0	0	0	0	0
2	0.1	0	0	0.1	0	0	0	0	0.1	0	0.03	0.048304589
1	0	0.1	0	0.1	0	0.1	0.1	0	0.1	0	0.05	0.052704628
0	0.2	0.1	0.1	0	0.2	0.1	0.2	0.1	0	0	0.1	0.081649658
-1	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0	0.1	0.14	0.06992059
-2	0	0.1	0.1	0.2	0.2	0.3	0.2	0.3	0.1	0.3	0.18	0.103279556
-5	0.1	0.1	0.2	0.2	0.1	0.3	0.1	0.2	0.2	0.3	0.18	0.078891864
-10	0.4	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0	0.3	0.23	0.078891864
-20	0.6	0.7	0.7	0.6	0.5	0.6	0.5	0.4	0.4	0.4	0.54	0.1117378779
-40	0.6	0.4	0.4	0.6	0.5	0.6	0.4	0.4	0.4	0.7	0.5	0.115470054
-60	0.9	0.5	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.6	0.52	0.154919334

Table 1 Data results for simulation runs of ASK

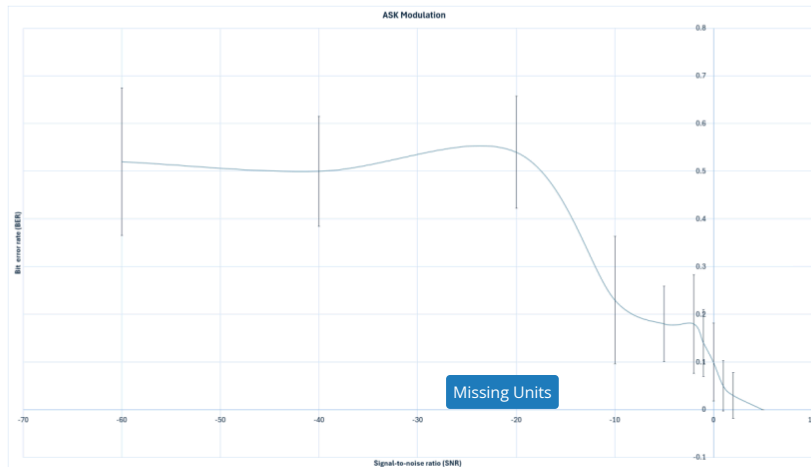


Figure 2 Graph of SNR against BER for ASK

Phase Shift Keying (PSK) Modulation

Overview and Background

Phase Shift Keying (PSK) modulation is similar to ASK modulation, however instead of varying the amplitude, the phase of the carrier signal is varied. In PSK modulation this is done by precisely varying the sine and cosine waves of the carrier signal at very specific times. The most common form of PSK utilises just two phase states – usually 0 degrees and 180 degrees. By varying the phase the modulator can encode the data stream within the modulation signal.

Relative to other modulation schemes such as ASK, PSK modulation is a quite power efficient modulation scheme. It is also possible to use higher levels of PSK such as QPSK to enable quite high data rates within the transmission, although this does not apply to the base version of PSK. On the other hand, PSK requires both the transmitter and receiver to either guess the phase state or requires a form of synchronisation between the transmitter and receiver, which adds complexity and can make it more vulnerable to errors [6].

Due to its characteristics, PSK modulation is commonly used for things such as wireless communication such as in RFID systems and Bluetooth communication systems [7].

Simulink Modelling

Shown in Figure X below is the MATLAB Simulink model of PSK used to generate the results on how the modulation scheme handles noise. It consists of a modulation

section, an AWGN channel to simulate interference, a demodulation section, and a bit error rate calculation.

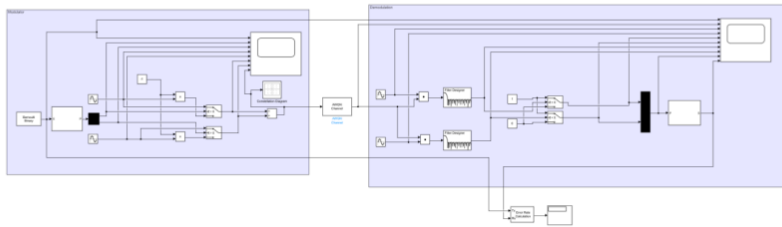


Figure 3 Simulink Model of PSK

Simulation Results

A series of tests were performed on the model, calculating the bit error rate (BER) at different noise levels on the AWGN. 10 different BER values were calculated for each noise level, demonstrating noise levels where the modulation scheme had no errors whatsoever to the point at which the BER reached of approximately 0.5. A BER of approximately 0.5 is considered a critical failure because at this point, the simulation is getting the correct values 50% of the time which is the same as just guessing one way or another.

Average BER values were then calculated for each signal-to-noise ratio (SNR) value as well as standard deviations of the data. This allowed the creation of the table and graph seen below which demonstrates the point at which the modulation scheme suffered what level of failure due to the noise levels.

SNR	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Average	Standard Deviation
5	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0.005	0	0	0.005	0	0.005	0	0	0.0015	0.002415229
-2	0.005	0.01	0.005	0.01	0.01	0.005	0.01	0.01	0.01	0.01	0.0085	0.00608
-5	0.055	0.071	0.055	0.05	0.045	0.071	0.065	0.055	0.076	0.065	0.0608	0.01646174
-10	0.187	0.208	0.228	0.167	0.208	0.198	0.187	0.208	0.192	0.198	0.1981	0.015368077
-20	0.401	0.385	0.38	0.37	0.39	0.38	0.36	0.36	0.401	0.365	0.3792	0.036285289
-40	0.472	0.487	0.512	0.446	0.538	0.522	0.421	0.451	0.472	0.487	0.4808	0.030277238
-60	0.512	0.497	0.487	0.446	0.512	0.553	0.497	0.461	0.522	0.507	0.4994	

Table 2 Data results for simulation runs of PSK

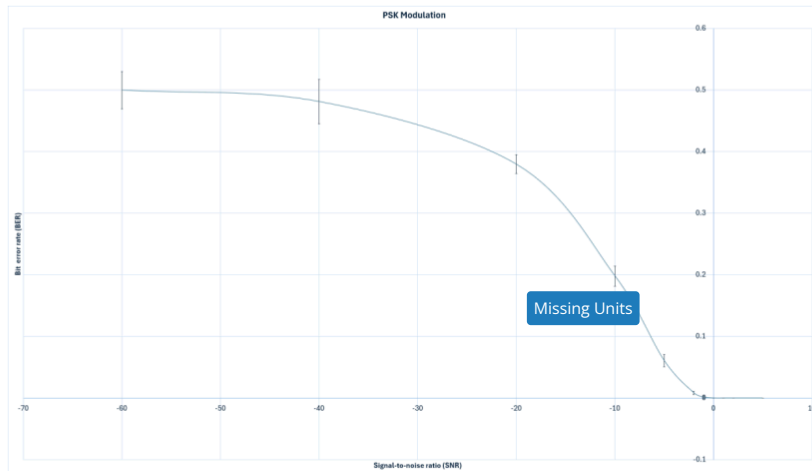


Figure 4 Graph of SNR against BER for PSK

Quadrature Phase Shift Keying (QPSK) Modulation

Overview and Background

Quadrature Phase Shift Keying (QPSK) modulation is a modulation scheme that builds upon Phase Shift Keying (PSK) modulation in order to gain some advantages. QPSK works in the same fundamental way as PSK modulation, except instead of utilizing only 2 phase states, QPSK utilizes a higher number – usually 8 phase states.

By using more phase states, QPSK is able to transmit at a significantly higher data rate than a number of other modulation schemes – even – however it also carries some of the benefits of PSK modulation such as the good power efficiency due to a lack of change in the amplitude of the signal. It does unfortunately suffer from one pretty major drawback – due to the number of phases and complexity of QPSK overall, it requires a significantly more complex level of circuitry which can add cost, time and increase the chance of an error in the circuitry occurring [8].

Due to its particularly high data rate, QPSK has become popular for a number of high data rate transfers such as video teleconferencing and wireless LAN technologies [9].

Simulink Modelling

Shown in [Figure 14](#) below is the MATLAB Simulink model of QPSK used to generate the results on how the modulation scheme handles noise. It consists of a modulation section, an AWGN channel to simulate interference, a demodulation section, and a bit error rate calculation.

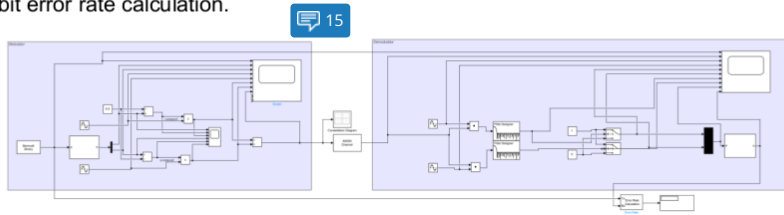


Figure 5 Simulink Model of QPSK

Simulation Results

A series of tests were performed on the model, calculating the bit error rate (BER) at different noise levels on the AWGN. 10 different BER values were calculated for each noise level, demonstrating noise levels where the modulation scheme had no errors whatsoever to the point at which the BER reached of approximately 0.5. A BER of approximately 0.5 is considered a critical failure because at this point, the simulation is getting the correct values 50% of the time which is the same as just guessing one way or another.

Average BER values were then calculated for each signal-to-noise ratio (SNR) value as well as standard deviations of the data. This allowed the creation of the table and graph seen below which demonstrates the point at which the modulation scheme suffered what level of failure due to the noise levels.

SNR	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Average	Standard Deviation
5	0	0	0	0	0	0	0	0	0	0	0	0
2	0.058	0.117	0.058	0.058	0.117	0	0	0.058	0.058	0.058	0.0582	0.039000855
1	0.117	0.117	0.058	0.117	0.058	0.058	0.058	0.117	0.117	0.058	0.0875	0.03109573
0	0.058	0.058	0.117	0.117	0.058	0.058	0.058	0.117	0.117	0.117	0.0875	0.03109573
-1	0	0.058	0.117	0.117	0.176	0.176	0.235	0.176	0.117	0.176	0.1348	0.068190583
-2	0.176	0.235	0.235	0.235	0.176	0.176	0.235	0.117	0.235	0.176	0.1996	0.068190583
-5	0.294	0.352	0.294	0.235	0.235	0.235	0.235	0.411	0.235	0.117	0.2643	0.068190583
-10	0.325	0.352	0.352	0.47	0.117	0.411	0.411	0.325	0.411	0.411	0.3585	0.096671552
-20	0.47	0.395	0.47	0.511	0.588	0.588	0.588	0.647	0.352	0.411	0.502	0.098641889
-40	0.47	0.47	0.352	0.352	0.352	0.47	0.588	0.588	0.117	0.411	0.417	0.137283162
-60	0.117	0.709	0.588	0.511	0.511	0.511	0.352	0.352	0.709	0.47	0.483	0.177631329

Table 3 Data results for simulation runs of QPSK

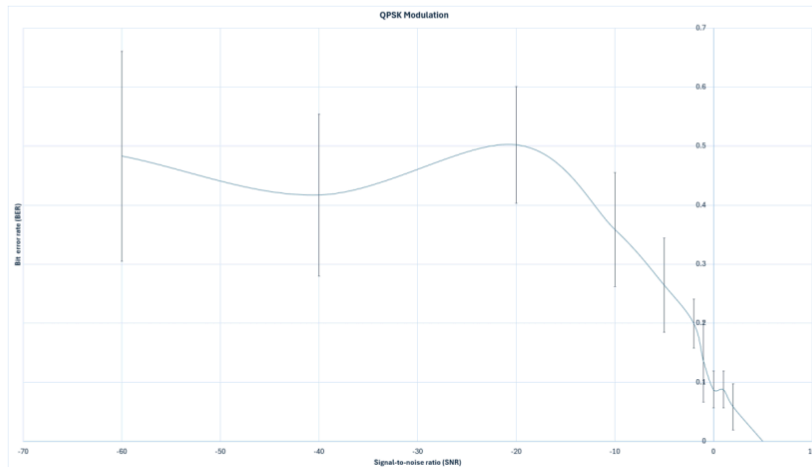


Figure 6 Graph of SNR against BER for QPSK

Quadrature Amplitude Modulation (QAM)

Overview and Background

Quadrature Amplitude Modulation (QAM) is a form of modulation that takes the changes used in PSK and ASK in order to attempt to increase the data rate without affecting the bandwidth. QAM does this by taking 2 signals instead of 1 which are the same frequency but are separated by a 90 degree phase difference, modulating the data into them and then combining the signals into 1 carrier wave. This enables a huge number of potential modifications to be made to the system in order to increase the number of points available to identify data.

Due to how QAM works, its primary inherent advantage is the huge data rates possible with QAM. By shifting the points as close as possible QAM is able to achieve data rates far higher than other modulation schemes such as QPSK or ASK. Unfortunately however this does come with a number of drawbacks, primarily with accuracy. Due to how compressed together the data points are in the signal, QAM is significantly more susceptible to noise than other modulation schemes as even minor changes in the signal due to interference can cause significant data loss [10].

These characteristics makes QAM a popular choice for high data rate applications such as Wi-Fi networking and satellite communications [11].

Simulink Modelling

Shown in Figure X below is the MATLAB Simulink model of QPSK used to generate the results on how the modulation scheme handles noise. It consists of a modulation

section, an AWGN channel to simulate interference, a demodulation section, and a bit error rate calculation. Similarly to the ASK modulation model, a time delay was also used here in order to calibrate the transmitted and received signals for the bit error rate calculation.

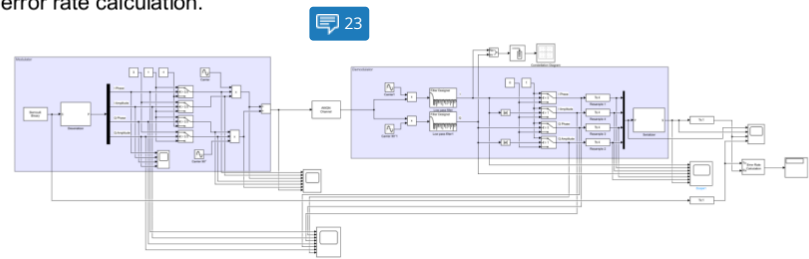


Figure 7 Simulink Model of QAM

Simulation Results

A series of tests were performed on the model, calculating the bit error rate (BER) at different noise levels on the AWGN. 10 different BER values were calculated for each noise level, demonstrating noise levels where the modulation scheme had no errors whatsoever to the point at which the BER reached of approximately 0.5. A BER of approximately 0.5 is considered a critical failure because at this point, the simulation is getting the correct values 50% of the time which is the same as just guessing one way or another.

Average BER values were then calculated for each signal-to-noise ratio (SNR) value as well as standard deviations of the data. This allowed the creation of the table and graph seen below which demonstrates the point at which the modulation scheme suffered what level of failure due to the noise levels.

SNR	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Average	Standard Deviation
5	0	0	0.002	0	0	0.002	0.002	0	0	0	0.0006	0.000966092
2	0	0	0	0	0.002	0.002	0	0	0.002	0.002	0.0008	0.001032796
1	0.002	0	0	0.002	0.002	0.002	0	0	0.002	0.002	0.0012	0.001032796
0	0.002	0.002	0.002	0.004	0.002	0.002	0.004	0.002	0.004	0.002	0.0026	0.000966092
-1	0.008	0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.008	0.0052	0.001932184
-2	0.012	0.02	0.012	0.014	0.01	0.02	0.012	0.01	0.01	0.02	0.014	0.004320494
-5	0.034	0.048	0.044	0.034	0.036	0.05	0.034	0.058	0.034	0.012	0.0384	0.012571573
-10	0.157	0.114	0.134	0.152	0.152	0.129	0.135	0.117	0.098	0.117	0.1305	0.019306015
-20	0.351	0.367	0.381	0.361	0.399	0.399	0.381	0.354	0.33	0.369	0.3692	0.021668205
-40	0.486	0.454	0.476	0.476	0.448	0.486	0.507	0.507	0.448	0.486	0.4774	0.021741921
-60	0.517	0.507	0.507	0.486	0.507	0.513	0.497	0.525	0.494	0.509	0.5062	0.011390054

Table 4 Data results for simulation runs of QAM

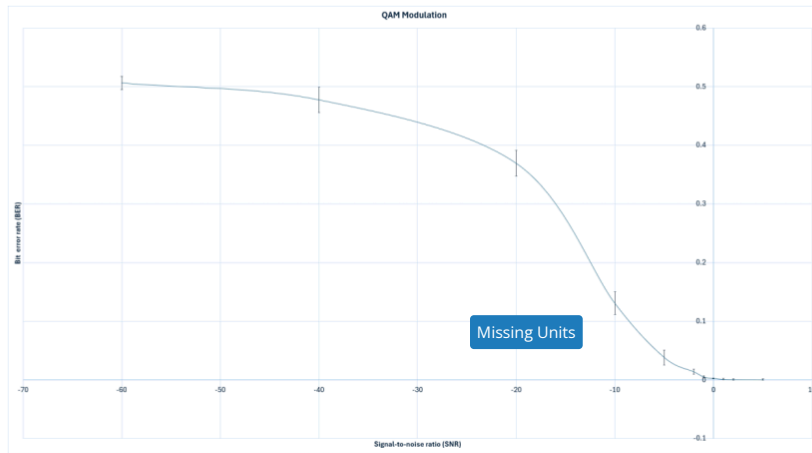


Figure 8 Graph of SNR against BER for QAM

Conclusion and Evaluation

25

In conclusion, whilst this report has showcased a variety of information that describes and demonstrates the capabilities and methodology of a number of modulation schemes, the actual data obtained from the simulation appears to be unreliable and does not properly coincide with what should have been expected.

26

This is likely due to the typical issues of simulation vs theoretical as no simulation is perfect and a number of errors can often occur which creates differences between the theoretical values, simulated values and the practical real world values [12].

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Molly Scarlet DSP and Comms Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

40/100

PAGE 1



Comment 1

You abstract should also include a more description of what you have done, along with a statement of your results

PAGE 2

PAGE 3

PAGE 4



Colloquialism

You should not use colloquialisms in formal writing.

PAGE 5



Comment 2

What are the benefits of using a random data source over a predetermined data set?



Comment 3

Figure 1?

You should proofread your work prior to submission to identify errors like this.

Maybe you should highlight it when it is first typed so that it can be seen more easily and fixed later



Comment 4

Why is this needed? What is the delay compensating for?

PAGE 6



Comment 5

They have captions. You should refer to them by their details.

The results can be seen in Table 1 and Figure 2.

QM

recreate table

You should recreate tables in Word rather than copy and paste them from excel. Recreating them will give a more professional looking result.

PAGE 7

QM

Missing Units

What units is this in?

You should always include the units for all quantities you describe in your text. Some quantities have more than one unit. Frequency, for example, can be measured in Hertz (Hz) or radians per sec (rad/s).

Make it clear for your reader and remove any ambiguity.



Comment 6

PSK only uses a single carrier wave. How can it have sine and cosine components?



Comment 7

two not 2



Comment 8

Do you mean Binary Phase Shift Keying (BPSK)?



Comment 9

You should include more detail here - what do each of the blocks do?

PAGE 8



Comment 10

You have already stated this above.



Comment 11

You have already stated this for the previous method. Could you not have structured your report so that you introduced the experiment details, then the models, then all the results together. That way you would not be repeating paragraphs.

QM

recreate table

You should recreate tables in Word rather than copy and paste them from excel. Recreating them will give a more professional looking result.

PAGE 9

QM

Missing Units

What units is this in?

You should always include the units for all quantities you describe in your text. Some quantities have more than one unit. Frequency, for example, can be measured in Hertz (Hz) or radians per sec (rad/s).

Make it clear for your reader and remove any ambiguity.



Comment 12

QPSK, or Quadrature Phase Shift Keying uses only FOUR phases. PSK that has 8 states is called 8-PSK



Comment 13

This part does not make sense.

PAGE 10



Comment 14

Figure 5?

See previous comment on Figure X (1) above.



Comment 15

More detail on the model is needed -

What do the blocks do?

How does this perform the modulation required?



Comment 16

Repetition



recreate table

You should recreate tables in Word rather than copy and paste them from excel. Recreating them will give a more professional looking result.

PAGE 11



Comment 17

one not 1



Comment 18

two not 2



Comment 19

one not 1



Comment 20

two not 2



Comment 21

This first paragraph could equally be talking about QPSK. What differentiates QAM from QPSK?



Comment 22

You need to be more precise in what you say. The data points occupy the same, if not more space in the time domain signal. I presume you mean the density of the points in the constellation diagram is higher, therefore a lower level of noise can cause bit errors to occur more easily. The noise added to the signal during transmission moves the received data point in the constellation diagram, to a neighbouring location which is interpreted as a bit error.

PAGE 12



Comment 23

Same comments as previously -

What is the delay for?

What do all the blocks in the model do?

How does this modulate?

More detail required.



Comment 24

Repetition.

PAGE 13



Missing Units

What units is this in?

You should always include the units for all quantities you describe in your text. Some quantities have more than one unit. Frequency, for example, can be measured in Hertz (Hz) or radians per sec (rad/s).

Make it clear for your reader and remove any ambiguity.



Comment 25

You have not presented any analysis of the results.

How do they compare to one another?

Why is one better than another?

What makes one more tolerant to noise than others?

Which is more efficient for data throughput?



Comment 26

regardless of how the data fits with your preconception of what the results should be, you should not allow that to skew your attitude to analysing it properly. If all scientists allowed their

preconceptions to overshadow analysis, they wouldn't bother to do any experiments and we would not advance.

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.

QM

Refs missing info

Some of your references are missing information. To understand what information should be included, see the university IEEE referencing handbook on the library website.

https://uwtsd.ac.uk/media/uwtsd-website/content-assets/documents/library-and-learning-resources/infoskills/IEEE-eng_v.1.2.pdf

Additional Comment

No access date

QM

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MOLLY SCARLET

39.80

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



"Inclusion of a wide range of research-informed literature, including sources retrieved independently.

6.3

Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied."

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Evidence of basic knowledge and understanding of the relevant concepts and underlying principles. Much more detail is required.

8

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance. Your results look ok, but you have not analysed them at all, yet you make conclusions stating they were not what you expected. What did you expect them to be? What did your results say?

9

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



An adequate awareness and mostly appropriate application of well-established methods, materials, tools and/or techniques. Basic appreciation of the context of the application. Models were ok, although no detail given on the functioning of them.

12

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate in a suitable format but with some room for improvement.

Work lacks coherence in places and could be better structured.

Whole sections of the report were repeated from previous sections. Images and tables presented but not directly referred to in the text.

4.5