

Fin Simulation of Digital Modulation Techniques

by Joseph Gillespie

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Simulation of Digital Modulation Techniques

DIGITAL SIGNAL PROCESSING AND
COMMUNICATIONS (ACDA5008)
JOSEPH GILLESPIE (2214885)

THE UNIVERSITY OF WAIYSEL TRINATEY ST DAVIDS | SA1 Waterfront Campus, IQ
Building

Abstract

This report aims to show the effect that White Gaussian Noise (WGN) has on four digital linear modulation and demodulation techniques that have been constructed within the software Matlab version R2024b. Each of these techniques have been made within the Simulink function within matlab, allowing for the addition of a WGN function that acts as the test's independent variable by increasing the signal-to-noise ratio through the tests. The results from each test have been plotted into a graph, explored more in section 2.0, and have been compared to each of the other modulation techniques within section 3.0.

The report begins with a breath introduction explaining modulation and demodulation before proceeding into section 1.0, which will develop further upon the modulation techniques used within the report and their construction within Simulink. Following this is the testing, results and comparison with a closing conclusion on results gathered throughout the test.

Abstract - results

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Introduction



Modulation allows for an effective method to transmit high- and low-speed data, depending on the modulation type, to a receiver. While at the same time compacting the signal into a designated band within the RF spectrum that subsequently prevents overcrowding and increases spectrum efficiency [1]. The way in which digital modulation achieves this is by encoding the data signal (the information signal) into the transmission signal frequency, amplitude and phase forming them into a singular signal [2]. The intended receiver then

demodulates this signal, meaning that the received signal is split back into its transmission signal and its information signal once at its destination.

The details in how a signal is modulated varies depending on whether the modulation is linear or nonlinear in technique and whether the data is required at high or low speeds. Within a linear technique, the transmission signal's phase/amplitude is affected when the information signal is applied. This can be seen in Quadrature Amplitude Modulation (QAM) and Phase Shift Keying (PSK) techniques [2]. In the case of non linear, the transmission signal is distorted and stretched. This results in this technique primarily being used within wired systems such as fibreoptics [3].

It is within this report that four linear digital modulation techniques will be investigated and tested against the effects of White Gaussian Noise (WGN) being injected into the system between the modulation and demodulation phases. The report shall begin with a brief operations description of each modulation method with a description of their Simulink design, followed by the results of each test and explanations of how each system performed with comparisons to one another.

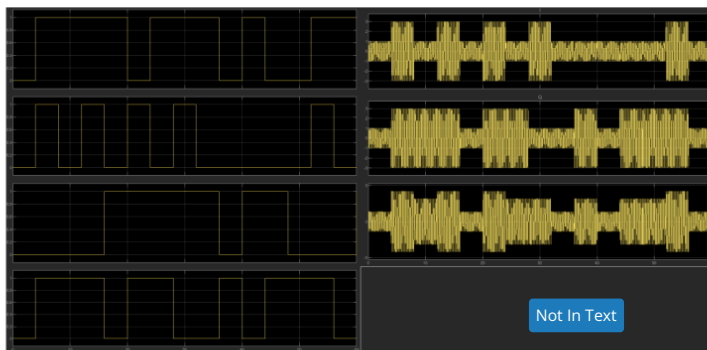


Figure 1, QAM Modulation

(1.0)Simulation Models

The modulation techniques that have been chosen to be tested within this report are Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), Quadratic Phase Shift Keying (QPSK), and Quadratic Amplitude Modulation (QAM). How these modulation techniques have been tested is by the addition of a WGN block between the modulation and demodulation phases of each system. This WGN block acts as the independent variable within the tests.

To calculate the Bit Error Rate (BER) of each test, a display block has been added that shows a comparison between the input information signal to the demodulated output of the

information signal, if the comparison is zero the signals are identical, if the comparison is above 0.5 then the technique has failed. It is these results that produce the dependent variables within the tests.

As for the control variables, the input data has been kept the same, all filter systems have the same settings, and the stop time has been set to 60. These have been kept consistent to allow for a fair test across all modulations.

The remaining parts of section 1.0 will briefly describe the operation and construction of each modulation technique.

(1.1) ASK

ASK is the most simplistic modulation technique primarily used for transmitting low-speed data. As a result, it is extremely susceptible to interference during transmissions [1].

Its susceptibility can be down to its simple method of modulation. As seen in Figure 2, ASK modulation only consists of two input signals, one being the information signal and the other the transmission, that are multiplied together. This multiplication block acts as a switch of sorts with the information signal being that of the trigger for the switch due to the information signal being binary. When a signal high (1) activates the switch, a burst of the transmission signal is released. On receiving a signal low (0), the switch prevents the release of the transmitter signal. This process continues until the information signal has finished its message [4].

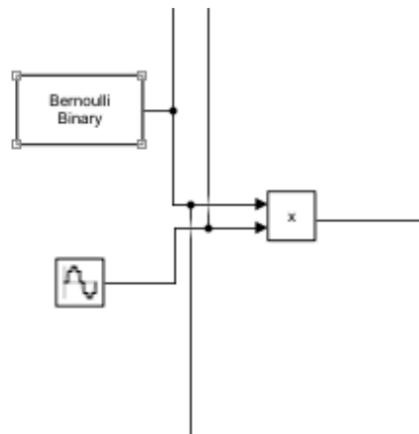


Figure 2, ASK Modulation

Demodulation takes place at the receiving end of the transmission and reverses that of the modulation process. In the case of ASK, there are two different demodulation methods envelope detection and coherent detection. The envelope detection method is the simplest of the two and utilises that of diodes, low-pass filters and threshold detection to receive the transmitted information [4].

Within this report and shown in Figure 3 is that of coherent detection. Within this method, a second signal is added to the demodulation process that matches that of the original transmission signal. This signal, along with the modulated signal, is mixed before entering a

filter which isolates the transmission and information signals. At this stage, a demodulator sets an amplitude threshold that signifies the 1 and 0 boundaries of the filtered signal resulting in the output being that of the original information signal [4].

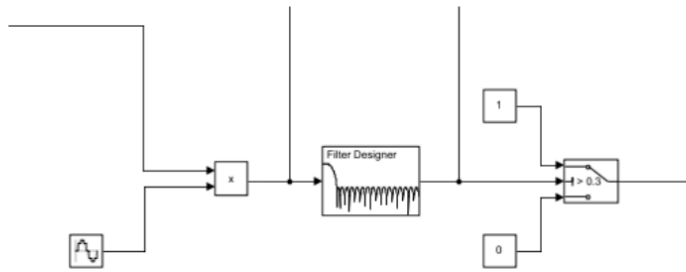


Figure 3, ASK Demodulation

Figure 4 displays the modulation and the demodulation process in signal form. The top left signal is the original information, whereas the bottom right signal is the demodulated output of the information.

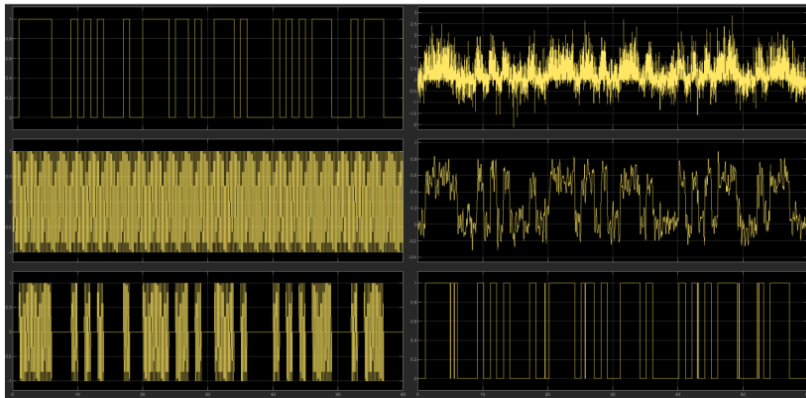


Figure 4, ASL Modulation & Demodulated Signals

(1.2) PSK

PSK is seen as a much more reliable and secure method of modulation with its primary use being that of high-speed data transmissions. With this in mind, there is a choice of two primary types of PSK modulation, Binary Phase Shift Keying (BPSK) and Quadratic Phase Shift Keying (QPSK) with the latter being investigated in section 1.3 [5].

The modulation method seen in Figure 5 is that of BPSK. BPSK utilizes that of two transmission frequencies that are 180° out of phase from one and over when modulating the information signal. When the binary information signal sends a 1 to the switch operation, the 180° transmission signal is activated. When a binary 0 is sent to the switch, the switch goes

to the transmission signal at 0° . This results in an M-shaped ripple ^{aver} ^{aver} positive or negative, respectively, which represents the start and end of an information transmission [6]. This M-shaped ripple can be seen in the bottom left of Figure 7.

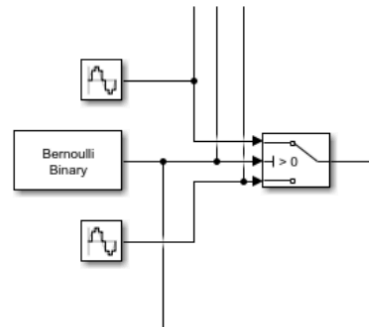


Figure 5, PSK Modulation

During the initial stages of demodulation, the modulated signal is split into two with one branch being mixed with a signal similar to the 180° transmission signal and the other branch being mixed with a similar 0° signal. These two signals are then brought back together but this time, the 0° phase signal is taken away from the 180° signal. This brings the polarity of the signal into a fairly correct configuration before it is put into a filter that forms the correct shape of the information signal. The final stage of this modulation results in trigger boundaries being set that activate whether the signal is a trigger high or low depending on the switch threshold.

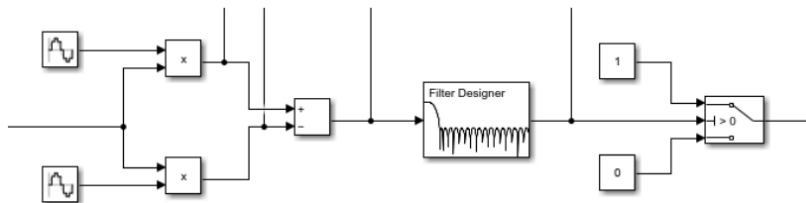


Figure 6, PSK Demodulation

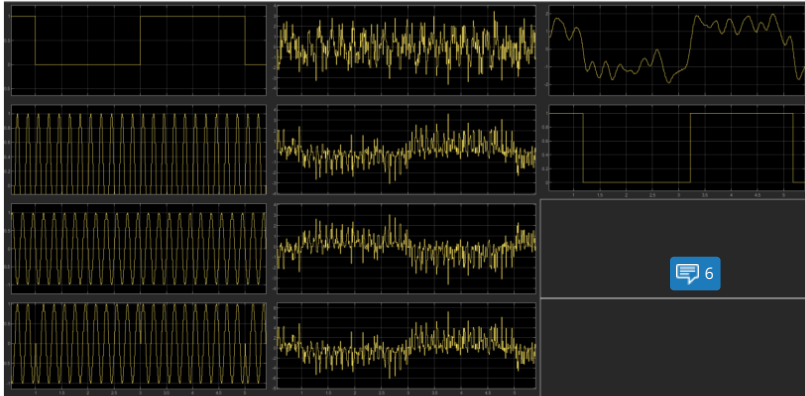


Figure 7, BPSK Modulation & Demodulation

(1.3) QPSK

At a top level, QPSK operates similarly to that of PSK and can be seen operating in systems such as satellite communication due to this, but it is within this method of modulation where QPSK differs quite substantially from its PSK counterpart.

How QPSK differs is due to its transmission style. Whereas modulators transmit one-bit symbol at a time, QPSK transmutes two. This is accomplished by the carrier signal not being limited to two states but four. Each of these four-phase shifts sits at 45° , 135° , 225° and 315° from each other [7].

Figure 8 shows the modulation method QPSK takes. It is critical to take note that the information signal is split into two where it meets a switch that activates under specified triggers. Once one of these triggers is met, a mixed signal is triggered or that of an untarnished one. This happens for both splits and once the switches have let from their respective signal they are added together before transmission.

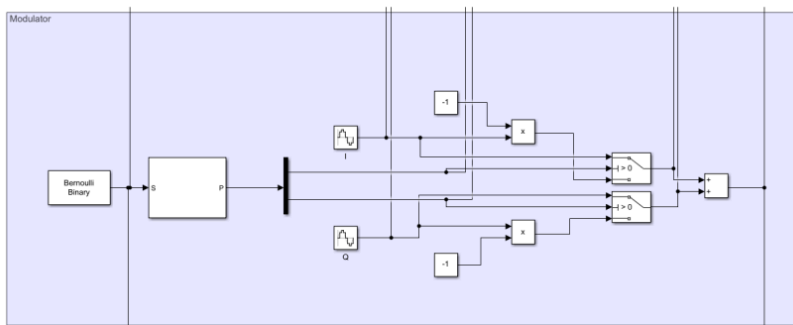


Figure 8, QPSK Modulation

Figure 9 shows the demodulation of QPSK. This is a reverse process of the modulation technique but with the added control filters.

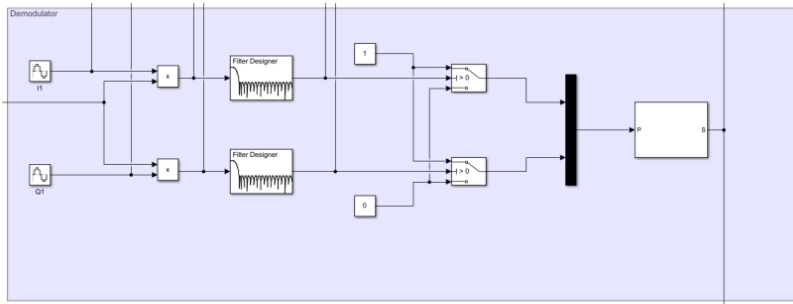


Figure 9, QPSK Demodulation

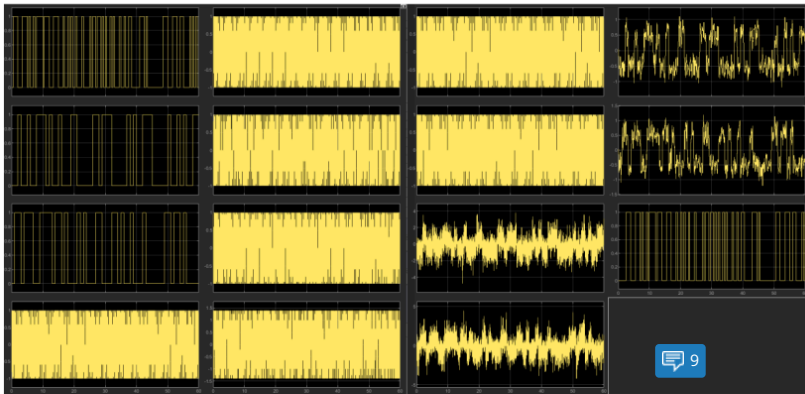


Figure 10, QPSK Signal Modulation & Demodulation

(1.4) QAM

QAM is primarily found within most high-speed systems today, ranging from mobile phones, WiFi and AM stereos to name just a few. The reasoning behind this is due to its capability of effectively utilising the RF spectrum, getting the most out of its limited space. Thereby allowing multiple transmission systems to operate within a given area and electromagnetic space [8].

When modulating in QAM, there are several different options to choose from. Each varies in the number of different combinations of amplitude and phase configurations that are used to transmit information [9]. For this report and in the case of Figure 11, QAM-16 has been chosen.

The modulation in Figure 11 works by splitting the information signal into four separate channels, that are further grouped into pairs with each being the quadrature (Q) and In-phase (I) signals [9]. Each signal then is placed into a switch with a high/low trigger at 0.5, when

10
11
a signal is above the threshold it will receive a constant set **aver** to 3, 1 or - 1. If the signal is below 0.5 the same activations, excluding 3, will be triggered. This operation designates the transmission position within the phase diagram aver to positions like 0000 (Top Left) or 1111 (Bottom Right).

After this phase, the signal is then mixed with its respective I or Q transmission signal before moving on to both the Q and I signals being added together and then transmitted.

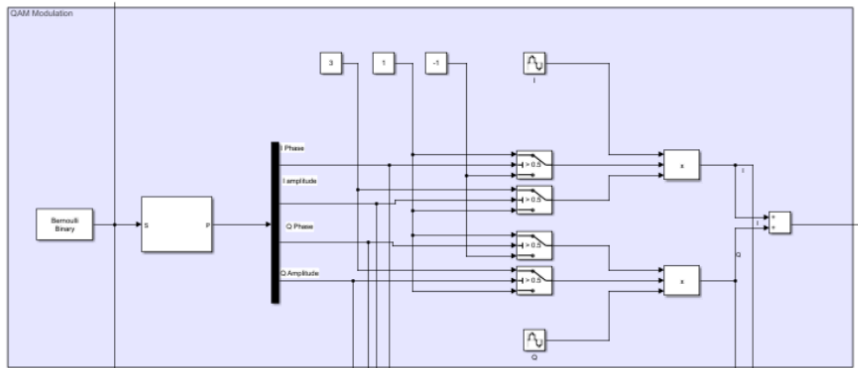


Figure 11, QAM Modulation

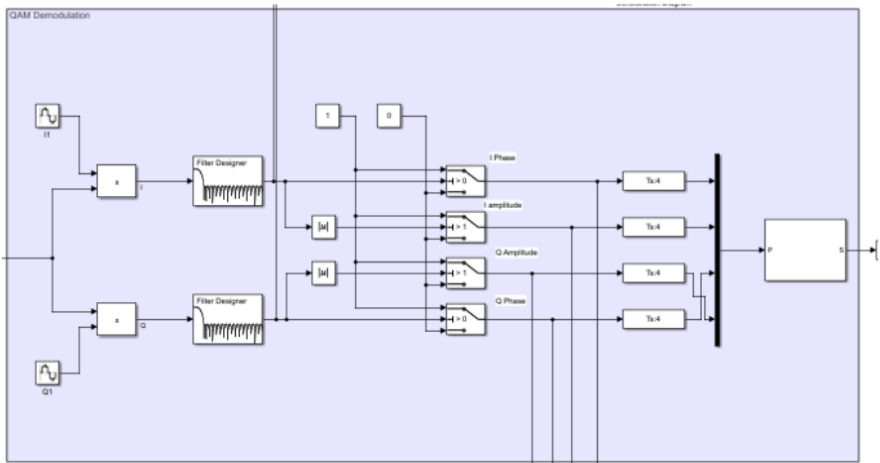


Figure 12, QAM Demodulation

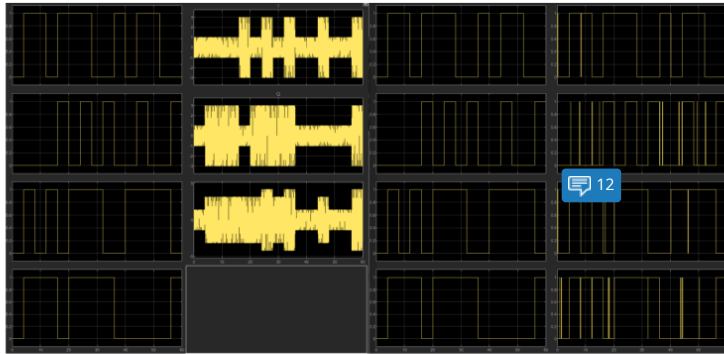


Figure 13, QAM Signal Modulation & Demodulation

(2.0) Results

The graphs within this section are the result of the average similarity of a series of tests performed at differing WGN frequencies. For each frequency, which decreased in increments of -5dB starting at 5dB, twenty test runs were carried out. The frequencies continued until two consecutive failures were recorded within the average calculations, with the failure mark standing at 0.5 error comparison. This marker represents a 50/50 accuracy within the demodulated signal compared to the input.

(2.1) ASK Plot

An unusual point to note with the ASK plot is that at a WGN level of 0dB, representing the noise being equal to the signal, the error comparison level is at 0.084. This shows interference within the signal even before true noise is added. Another point of interest occurs at -35dB, where the margin of error is significantly larger than its counterparts.

The first point of system failure accrues at -25dB before plunging between -30dB to -40dB and then truly failing at -45dB.

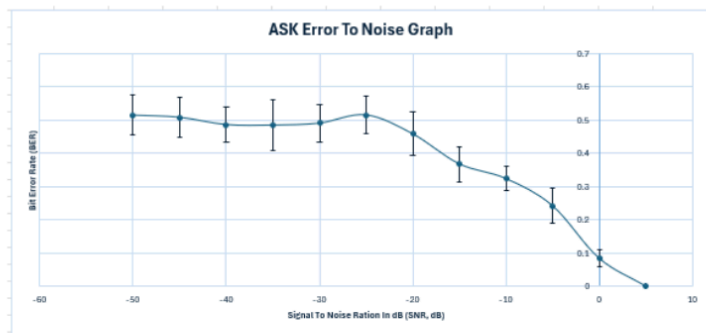


Figure 14, ASK Modulation Test Results

(2.2) PSK Plot

The PSK graph begins to Plato at -25dB to -55dB. From here the first error occurs at -60dB and again at -80dB before critically failing at -90dB.

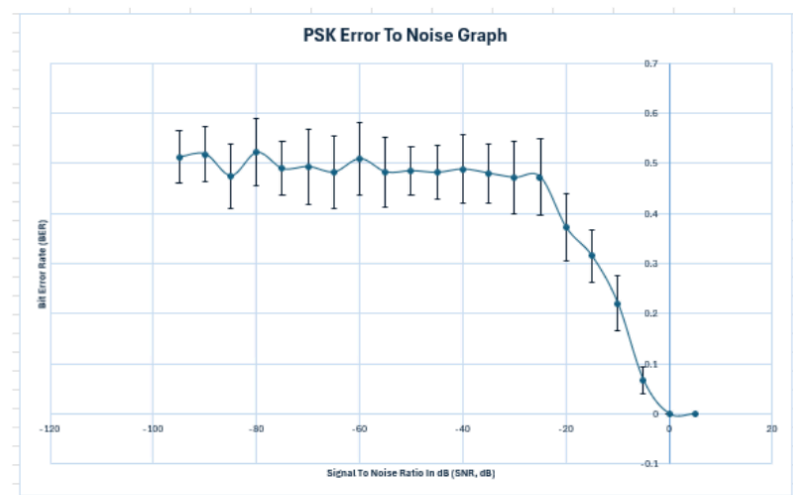


Figure 15, PSK Modulation Test Results

(2.3) QPSK Plot

QPSK begins with a steady incline to -30dB, where it plateaus out until -50dB. Critical failure occurs at -55dB with no failures before this point.

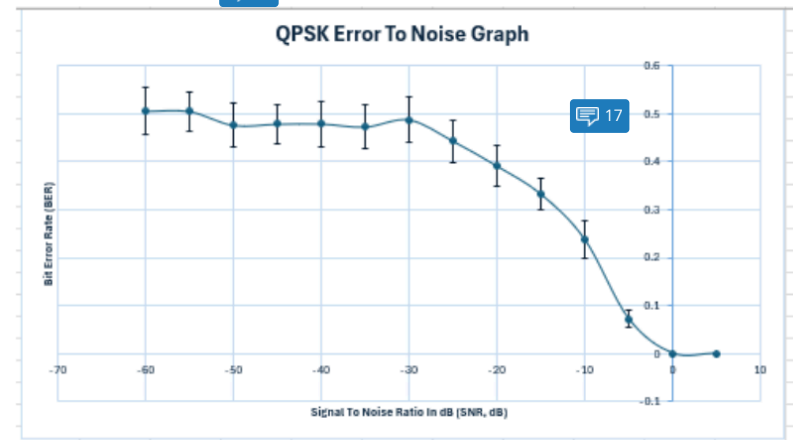


Figure 16, QPSK Modulation Test Results

(2.4) QAM Plot

The first instance of failure for QAM occurs at -35dB before it recovers at -40dB. After this point, at exactly -45dB, the QAM system critically fails.

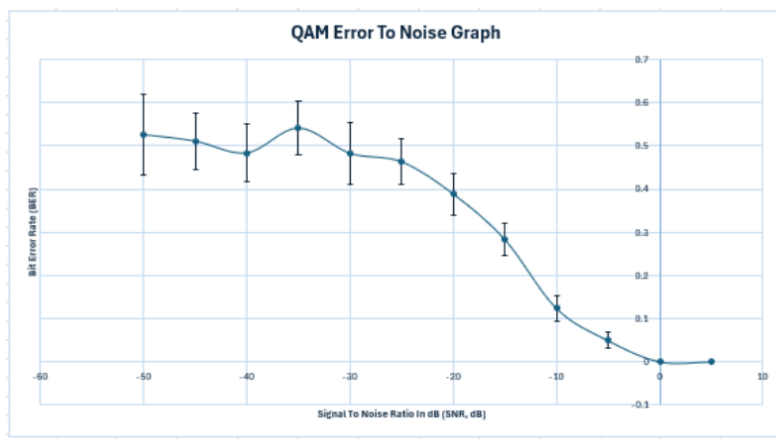


Figure 17, QAM Modulation Test Results

(3.0) Discussion

The graph shown in Figure 18 is a comparison of all the results gained from the tests performed in section 2.0. On first inspection of the comparison, there are some close similarities between all modulation techniques but under a more scrutiny, the similarities begin to fade. A prime example of this is ASK (Indicated by the blue line) where at the lower SNR, ASK is significantly more effected than the likes of its counterparts in QAM and PSK. ASK also is the first to fail at -25dB before critically failing at -45dB alongside QAM (indicated by the purple line). This result proves that ASK is significantly more sensitive to the effect of WGN compared to other modulation techniques.

From the results, QAM operates quite effectively at the lower end of the SNR. Outperforming all the other modulation techniques up until -20dB where it matches that of QPSK and PSK for a time. QAM has a significant failure at -35dB, 5dBs after the failure of ASK, before critically failing at the same point as ASK. This result has shown that QAM operates effectively at low noise levels but falters at higher levels of interference.

PSK (indicated by the orange line) and QPSK (Indicated by the dark green line) have strong similarities to one and other through the tests. With both modulation techniques following the same path in BER as the SNR increases. The two begin to deviate at -50dB where QPSK critically fails. This is shortly followed by PSK's first failure at -60dB before it continues to -90dB where it critically fails. From these results, it shows that QPSK is an extension of PSK and that both are effective at modulation even under the effect of WGN with both outperforming the other modulation techniques.

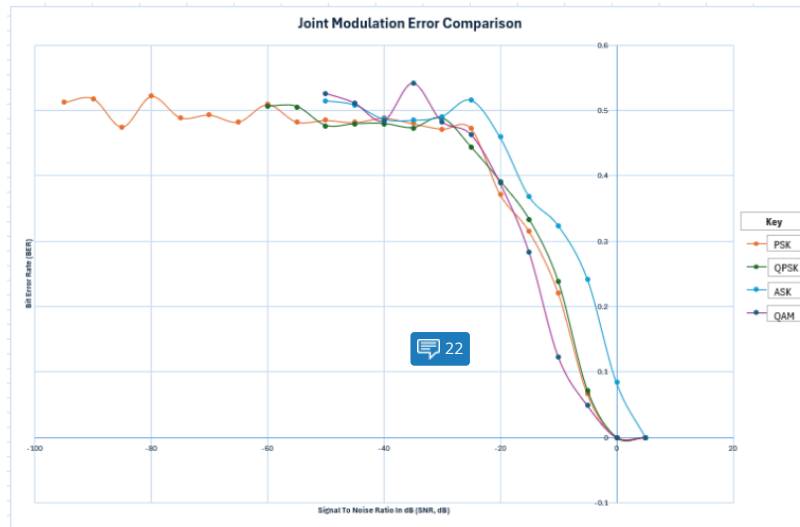


Figure 18, Comparison Results Graph

Conclusion

In this experiment, it has been determined that PSK is the most effective method of modulation and demodulation while under the effects of WGN. This is closely followed by QPSK which had a similar performance to PSK but reached its point of critical failure before that of PSK. The results gathered within this test were further supported by the twenty data points taken at each increment of WGN that resulted in the supporting graph seen throughout sections 2.0 and 3.0. The final conclusion proves that PSK is the most effective, all the other modulation techniques have performed quite similarly to one another especially when taking into account the margin of error each technique has.

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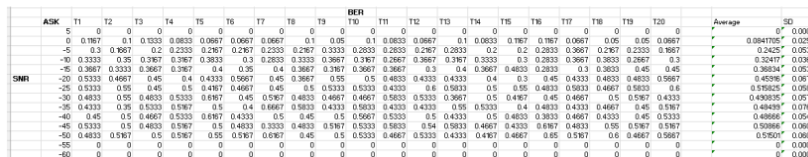
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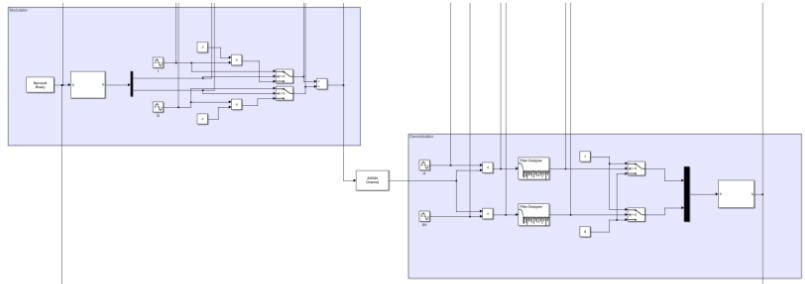
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Appendices

ASK and results table

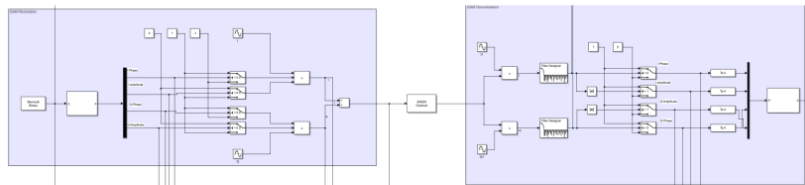
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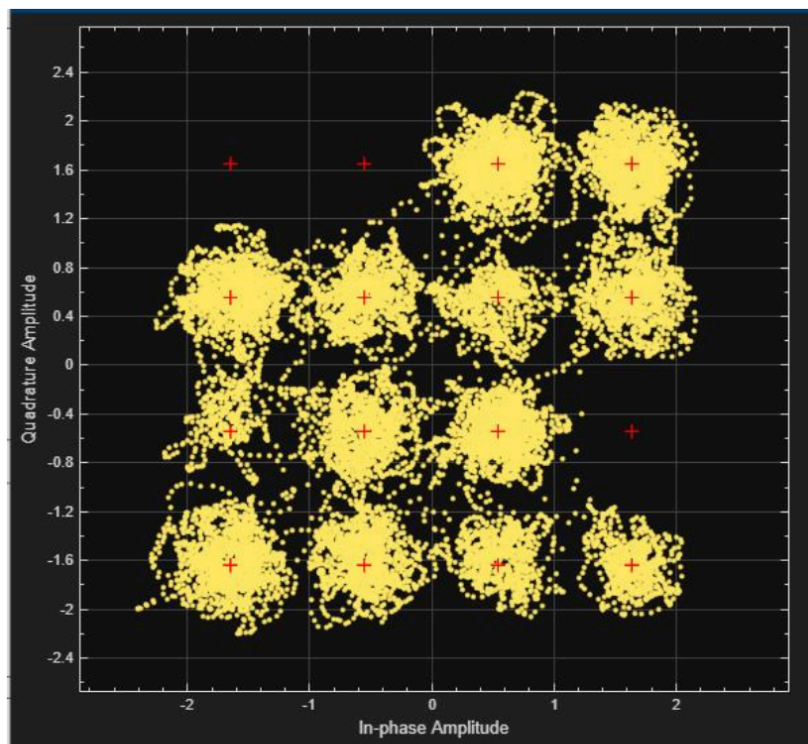


	BER																				Average	SD
QPSK	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20		
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	0.0536	0.0763	0.0684	0.1197	0.0427	0.054	0.0763	0.0763	0.0684	0.054	0.0536	0.0855	0.0536	0.0536	0.0855	0.0536	0.0763	0.0536	0.0536	0.0684	0.0536	0.072225
-10	0.2621	0.265	0.265	0.2684	0.1966	0.186	0.2398	0.1862	0.2051	0.2735	0.2268	0.2222	0.2051	0.2207	0.1962	0.2051	0.1966	0.2479	0.2222	0.2222	0.228835	2%
-15	0.3077	0.3846	0.3248	0.2821	0.3046	0.3077	0.3675	0.3333	0.2906	0.359	0.2201	0.3077	0.3240	0.359	0.359	0.2291	0.2391	0.359	0.3333	0.3761	0.359	0.332905
-20	0.3932	0.4274	0.393	0.3932	0.3932	0.4077	0.2991	0.4263	0.3846	0.3419	0.4274	0.3419	0.359	0.3932	0.4077	0.3333	0.453	0.3932	0.4615	0.4763	0.3932	0.391485
-25	0.4303	0.3846	0.5382	0.4188	0.4188	0.4444	0.453	0.4303	0.4872	0.453	0.3846	0.4444	0.4303	0.4444	0.4303	0.4188	0.5043	0.524	0.3875	0.4701	0.443275	4%
-30	0.4872	0.5274	0.5812	0.4815	0.4444	0.4701	0.4786	0.5129	0.4872	0.3846	0.5385	0.4274	0.4615	0.5385	0.4701	0.4701	0.4701	0.4786	0.5887	0.4872	0.488835	5%
-35	0.4701	0.4403	0.5239	0.4786	0.4872	0.4615	0.5726	0.4957	0.4615	0.4701	0.435	0.4444	0.4274	0.5274	0.453	0.4701	0.3932	0.4959	0.4957	0.547	0.47383	5%
-40	0.5556	0.5385	0.4444	0.453	0.4188	0.4355	0.5726	0.4701	0.4786	0.4701	0.4103	0.4701	0.5385	0.4444	0.4786	0.5385	0.4786	0.4355	0.453	0.5043	0.47343	5%
-45	0.453	0.4274	0.453	0.5043	0.5239	0.4957	0.4957	0.4388	0.4701	0.4615	0.4615	0.453	0.4957	0.5043	0.5556	0.5556	0.5129	0.4888	0.4701	0.4444	0.47388	4%
-50	0.4615	0.4786	0.4303	0.4957	0.5129	0.4872	0.5129	0.5385	0.4957	0.4615	0.5385	0.3846	0.4274	0.4274	0.5129	0.4701	0.435	0.453	0.5641	0.4303	0.47345	5%
-55	0.547	0.5129	0.4872	0.5556	0.5239	0.5385	0.4615	0.5043	0.4615	0.4786	0.4957	0.4786	0.5239	0.4957	0.547	0.4274	0.5043	0.5043	0.5385	0.453	0.505955	4%
-60	0.5912	0.4701	0.5887	0.5129	0.4444	0.4701	0.547	0.4786	0.4103	0.4444	0.5274	0.547	0.5043	0.5274	0.5239	0.4786	0.5726	0.4872	0.4615	0.505975	5%	

QAM, results table and phase diagram



		BER																				Average		SD
QAM		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18	T19	T20			
SM	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	-5	0.0377	0.0966	0.0377	0.0377	0.0566	0.0377	0.0966	0.0966	0.0785	0.0966	0.0966	0.0966	0.0785	0.0966	0.0785	0.0966	0.0785	0.0377	0.0377	0.0966	0.0377	0.049595	
	-10	0.1509	0.0785	0.1132	0.1132	0.0943	0.1509	0.1509	0.1321	0.1509	0.1321	0.1132	0.0943	0.1321	0.0943	0.1321	0.1132	0.0785	0.1509	0.1132	0.1509	0.1132	0.125678	
	-15	0.283	0.2642	0.2453	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.2642	0.0372	
	-20	0.3396	0.3079	0.434	0.434	0.434	0.434	0.434	0.3774	0.434	0.3774	0.434	0.3774	0.434	0.3774	0.434	0.3774	0.3962	0.434	0.434	0.3774	0.3774	0.048	
	-25	0.4951	0.5094	0.3774	0.5094	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.0535
	-30	0.3962	0.434	0.5094	0.6038	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.0625
	-35	0.6038	0.5094	0.5283	0.5472	0.4906	0.6038	0.5283	0.5283	0.5283	0.5283	0.5283	0.5283	0.5283	0.5283	0.5283	0.5283	0.5472	0.4906	0.4906	0.4906	0.4906	0.4906	0.0625
	-40	0.4528	0.4528	0.5283	0.5283	0.4906	0.434	0.3774	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.0657
	-45	0.4906	0.3774	0.5283	0.5472	0.4528	0.3774	0.5472	0.5094	0.5283	0.5094	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.0657
-50	0.4951	0.6038	0.5094	0.3962	0.4528	0.3962	0.5094	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.4906	0.0657	
-55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	



Fin Simulation of Digital Modulation Techniques

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

68/100

PAGE 1

PAGE 2

QM

Abstract - results

Good abstract, although you should include a statement of your results.

PAGE 3

PAGE 4



Comment 1

data?

PAGE 5



Comment 2

linear



Comment 3

Quadrature

QM

Not In Text

You have included a figure without mentioning it in the text. You should refer to the figure in the text, otherwise it is not worth including as the reader will not know what it relates to.

PAGE 6



Comment 4

fair

PAGE 7

PAGE 8



Comment 5

either

PAGE 9



Comment 6

You should state what each graph represents in relation to the model



Comment 7

via



Comment 8

through?

PAGE 10



Comment 9

See comment on Figure 7

PAGE 11



Comment 10

either



Comment 11

top left of what?

PAGE 12



Comment 12

What do each of these signals represent?



Comment 13

noise level



Comment 14

amplitudes, not frequencies



Comment 15

At 0dB the noise level is the same amplitude as the signal, this is like trying to order a drink in a noisy bar. Therefore this is "true noise".

PAGE 13



Comment 16

prior



Comment 17

You should copy the graph using copy - paste functions in excel rather than using a screen grabber. This allows you to get a higher quality image of the graph in your report.

PAGE 14



Comment 18

prior



Comment 19

scrutinous eye



Comment 20

quite



Comment 21

falters

PAGE 15



Comment 22

Nice graph, although you should use copy-paste within excel rather than a screen grabber.

PAGE 16



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

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For books, you should include page numbers of the section you have used.



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.



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.

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PAGE 19

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



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

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

6**KNOWLEDGE & UNDERSTANDING**

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



Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

13

A little more detail here would have helped greatly.

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.



"Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.

"

22.5

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods, materials, tools and/or techniques.
Very good consideration of the context of the application, with perceptive use of examples, where relevant.
Evidence of some innovation and creativity.

20.4

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 well, confidently and consistently in a suitable format.
Work is coherent and fluent and is well structured and organised

6