

DSP & COMMUNICATIONS

Evaluation of Amplitude Shift Key, Phase Shift Key and Quadrature Phase Shift Key digital modulation methods.

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ABSTRACT

Three digital modulations methods, Amplitude Shift Key (ASK), Phase Shift Key (PSK) and Quadrature Phase Shift Key (QPSK) were simulated using MATLAB to critically compare their performance.

During the testing of the digital modulation methods, bit error rate (BER) for each modulation method was measured with white gaussian noise gradually increased until the BER reached 50%.

It was found that ASK was the least resistant to noise (-39db). While PSK was the most resistant to noise followed (-57db) by QPSK (-50db). However, despite PSK having a higher resistant to noise QPSK has the benefit of transmitting 2 bits of data per symbol. While ASK is inexpensive and less complicated to manufacture.

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Introduction

Wireless communications in the 21st century has increased in demand due to the rise in homeworking. [1] During the transmission of data from the mentioned digital modulation methods (ASK, PSK, and QPSK), other radio waves and wavelengths could interfere with the original transmitted data. Corrupting the data being transmitted and making working from home more difficult due to longer times sending more data to repair the original data transmission.

As a result, this report investigates the noise resistance of ASK, PSK and QPSK to determine how suitable they are transmitting data. Furthermore, this report discusses the data sent per symbol and the method to modulate and demodulate the data in ASK, PSK, and QPSK.

Background Information

Binary

Computers use thousands of transistors to operate [2]. A transistor is a switch with two states, which can be assigned variables. When the switch is on, a signal can pass allowing a value of 1, while if the switch is off then no signal can pass resulting a value of 0. If two switches are combining this allows for greater values to be stored and different data types of data to be stored. Equally if 8 bits are used this can create a byte, which has 256 different values and can be used to store letters. For example in ASCII.

Binary Bit	Binary 2 Bits	
0	00	10
1	01	11

Binary 4 Bit Combinations			
0000	0100	1000	1100
0001	0101	1001	1101
0010	0110	1010	1110
0011	0111	1011	1111

Figure No.1

Continuous to Digital Data

Binary is known as machine code [3] and allows technology to operate. For computers to understand continuous data, they need to take many samples and record the amplitude using binary.

Imagine a speaker on the radio, singing into a microphone. The microphone detects the peaks and troughs of the voice, which is continuous data. However, to transmit this data for the machines to understand, it must be converted into machine code.

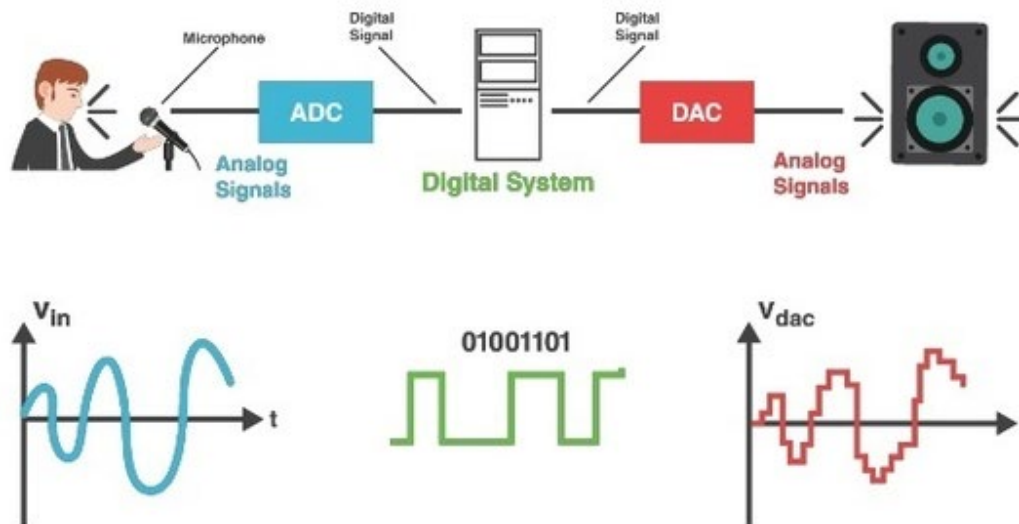


Figure No.2 [4]

To solve this scenario, the waveform is broken down into samples and each of the amplitude is measured in binary. The binary is then modulated and transmitted for the audience to listen. Once a car radio picks up the waveforms emitted, they are then demodulated. This will allow the speaker to replicate the amplitudes of each sample replicating the waveform allowing the listener to hear music.

Digital Modulation Methods:

Amplitude Shift Keying (ASK)

This type of digital modulation uses on-off keying (OOK) [5] to rapidly turn on and off a carrier wave creating bursts of waveforms. To represent the symbols 1 and 0, when a burst of the carrier waveform is detected this is recognised as a 1. While if no waveform is detected then this is considered the 0 symbol. Different amplitudes of the waveform can be used to transfer different symbols, this would be known as quadrature amplitude modulation. ASK only uses two discrete values which is the peak of the waveform and no waveform. Therefore, only 1 bit of data can be sent at one time.

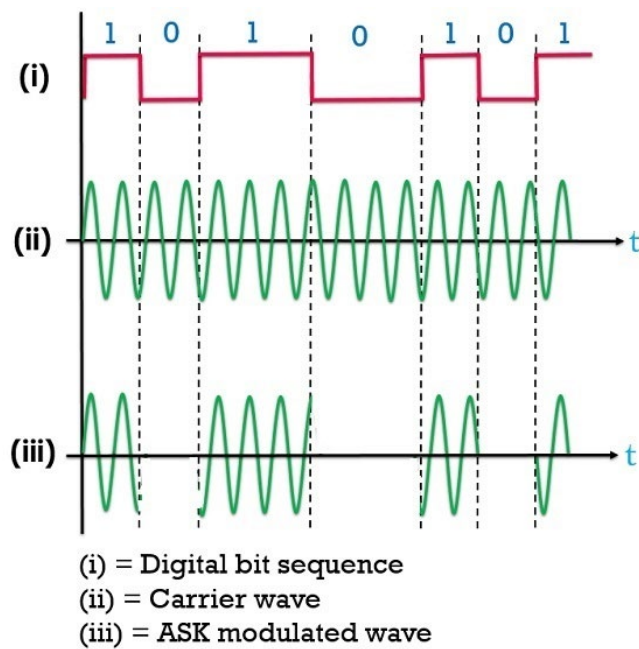


Figure No.3 [6]

Examples of ASK can be found in led transmitters and optical cables. When the light is being emitted this creates a waveform in the light visible light spectrum. Therefore, this is received as a 1. While no light would represent a 0. ASK was also used in radio communications of Morse code. [7] Multiple bursts of wave were a dash, while singular bursts of wave were a dot. This would then be translated into alphabet characters.

Phase Shift Keying

Phase Shift Keying (sometimes known as Binary Phase Shift Keying – BPSK) uses a constant carrier wave, however, to differentiate between the symbols phase shifts are used. Similar to ASK, a switch is used to choose the symbols 0 and 1 however the amplitude of the peak is not affected. When a “0” symbol needs to be transmitted the waveform is not affected. To transmit a symbol of “1” a switch is used and diverts the wave through a delay which causes a phase shift of 180.

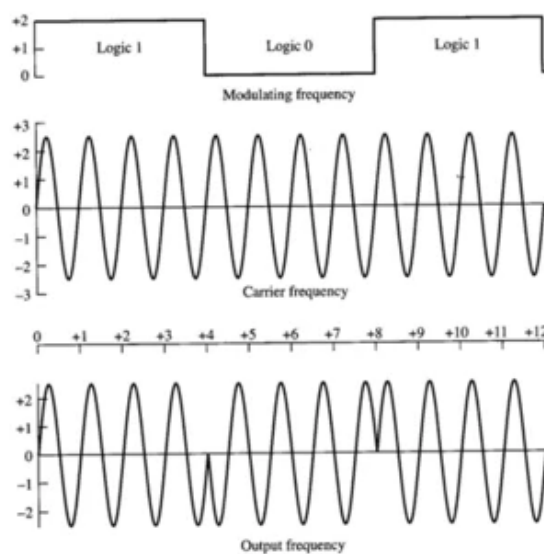


Figure No.4 [8]

Due to a constant wave being used instead of bursts from ASK, PSK is considered more energy efficient. [9] However, the disadvantages of PSK are during the modulation and demodulation it is more complex to measure the phase shift. This is due to the receiver not knowing the phase of the original carrier. To overcome this, a change in phase of 90 degrees is used. This is to give a distinct change in zero as the change in phase can be seen as a mirrored synchronisation of the waveform. [10]

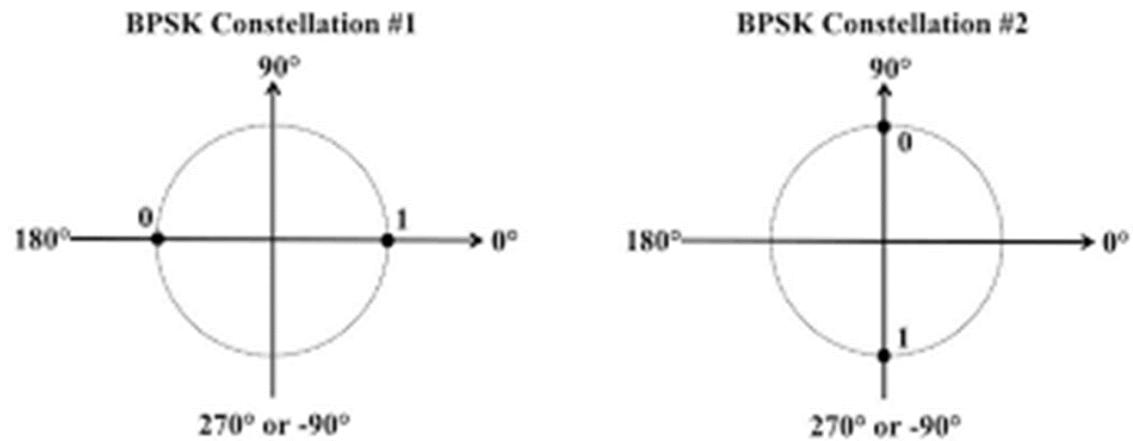


Figure No.5 [11]

Quadrature Phase Shift Keying

QPSK is used for satellite transmission and cable modem and cellular phone systems. [12]

QPSK can transfer two data bits per every symbol compared to PSK. Referring to binary, as two bits can be sent per symbol this allows four different combinations, as a result QPSK has four different symbols.

To achieve this, two separate waves are produced using the same carrier wave. One wave is unmodified, while the second has a 90-degree phase shift. The final output of the symbol is determined by the bits that enter each wave and the sum of the phase shift between the two waves.

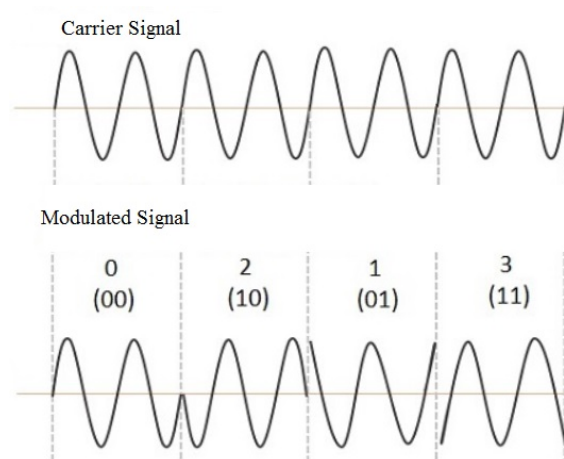
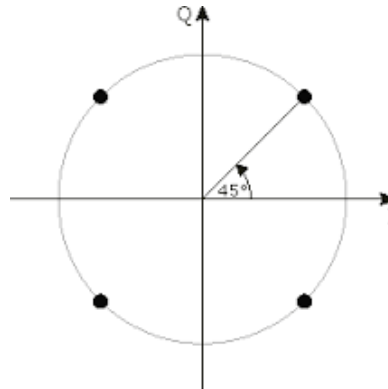


Figure No.6 [13]

Despite the higher bit rate per symbol the disadvantages of using QPSK are that the circuit is more complicated to construct. Additionally, more power is required to the increase of data being modulated and demodulated. [14] Finally, the transmitter and receiver must be synchronised at turning the constellation diagram, like in PSK does not work due to the increase of bits. As a result, QPSK is at risk of Intercarrier interference and requires filtering. [15]



QPSK constellation
Figure No.7 [16]

Method

To test the three digital modulation methods' an ASK, PSK and QPSK modulator and demodulator circuit was built using MATLAB. After the modulator and before the demodulator, the wavelength would pass through a gaussian white noise module; Adding noise to the wavelength being transmitted and received.

The white noise would be increased by -5db starting from 0db until the bit error rate reached 50%. This is because at 50%-bit error rate the data received would be unrecognisable and unlikely to be recovered.

A bit error module would calculate and compare the symbols produced at the beginning of the circuit to the symbols demodulate, calculating the bit error rate. For each test, the simulation would last 60 seconds. This was selected to ensure fast testing times and to ensure a substantial number of symbols to be produced and tested. Additionally, to replicate data be transmitted, the results could be easily transferred to symbols per minute. The test would be repeated five times.

Wavelength Amplitude:

The amplitude of each wavelength was 1. This was to reduce calculation errors and to improve the understanding of the scope during the assembly.

Wavelength Frequency and Sample Rate

The frequency of the wavelength was $2\pi * 50$, and the sample rate 1/5000.

Data Generation

To generate the data a Bernoulli equation was used. This would produce either a "0" symbol or "1" symbol with a 50% chance for each.

Filter Settings:

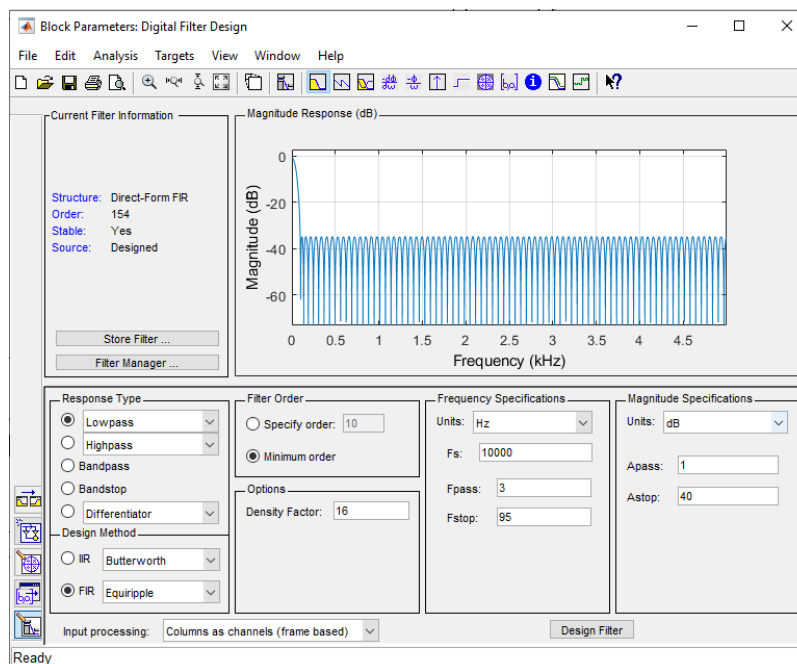
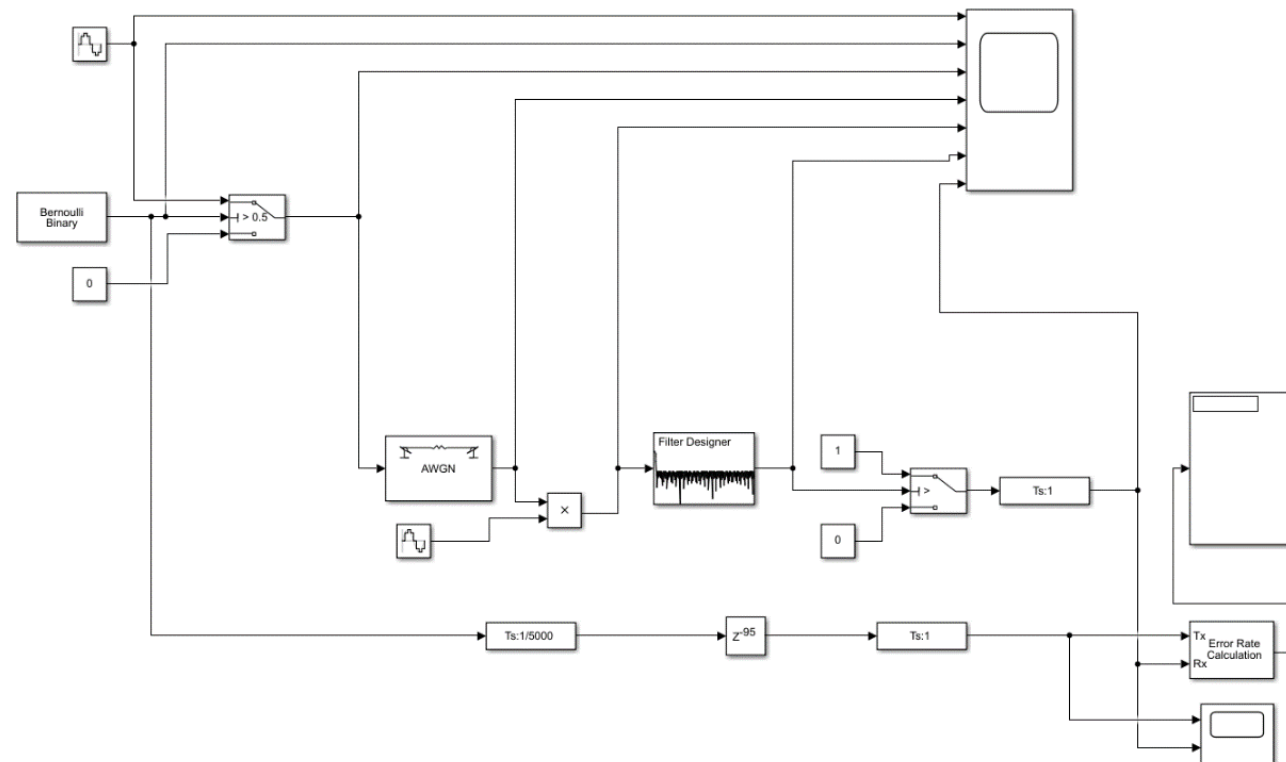


Figure No.8

ASK Circuit:

Modulation: To modulate the data a switch was used. When a 1 is given from the Bernoulli binary generator, the switch turns on allowing the sine wave to pass. When a 0 is given from the Bernoulli binary generator the switch remains off, passing no signal.

Demodulation: To demodulate the received wave, first the signal is multiplied by the original carrier wave. This will increase the frequency and ensure a positive wavelength throughout. The data then travels through a filter to remove the addition of the known wavelength to leave the original message. If the remaining data is over a threshold this will produce a 1. While if the data is under the threshold the switch will remain close, producing a 0.

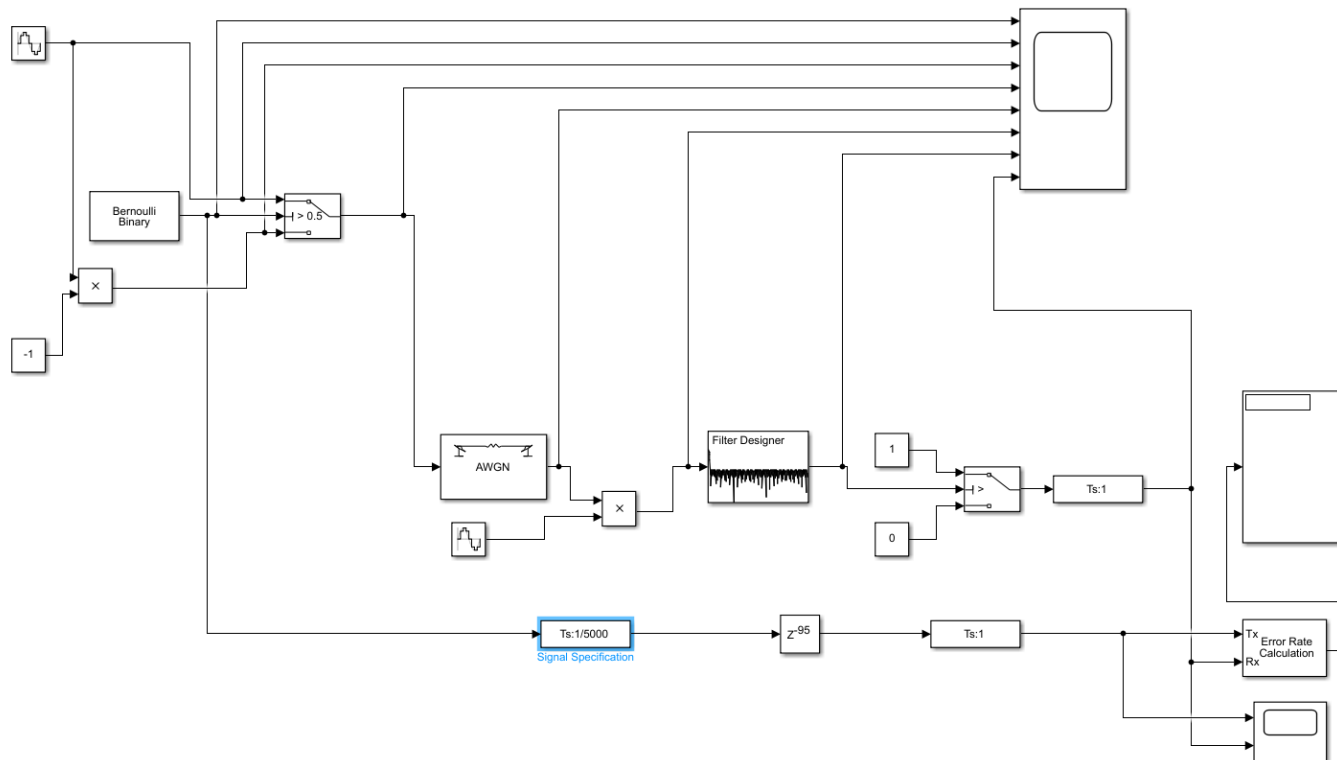


Schematic No.1

PSK Circuit Diagram

Modulation: When a 1 is given from the Bernoulli binary generator, the switch turns on allowing the sine wave to pass, with no change in phase shift. When a 0 is given from the Bernoulli binary generator the switch remains off, passing a modified sign wave that is out of phase by 180 degrees. As the amplitude has been multiplied by -1 this inverts the polarity without affecting the amplitude.

Demodulation: To demodulate the received wave, first the signal is multiplied by the original carrier wave. This will invert all peaks to a positive value or negative, depending on the phase further separating the values. The data then travels through a filter to remove the addition of the known wavelength to leave the original message. If the remaining data value is above 0, this will produce a 1. While if the remaining data value is below 0 this will produce a 0.

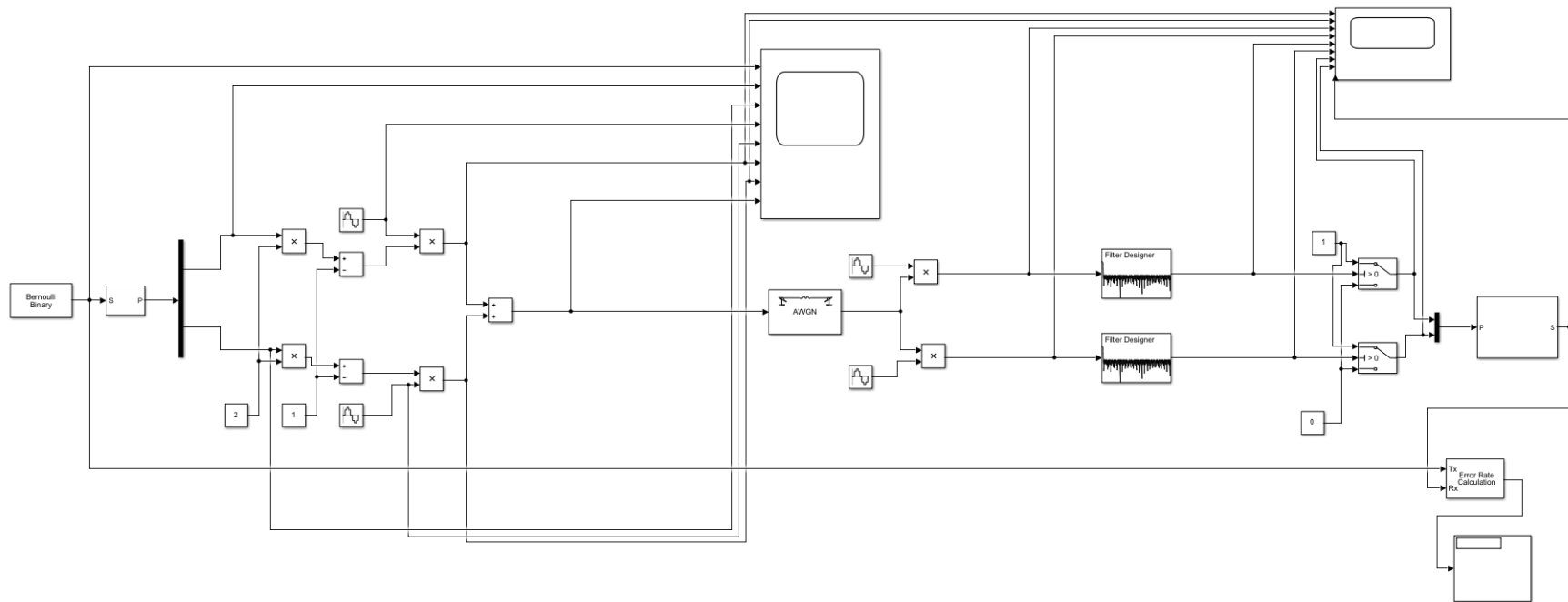


Schematic No.2

QPSK Circuit Diagram

Modulation: As the Bernoulli's binary generates values, these are gathered in pairs and split between two pathways. Both values are multiplied by the carrier wave, however the 2nd bit is multiplied by the carrier wave with a phase shift of 90 degrees. If the bits are 1 then a wave is created, while if the bits are 0 then no wave is created. Both waves, if generated, are taken and added together. The final wave with the difference in phase shift is then transmitted.

Demodulation: The received wave is multiplied by the original carrier wave, and the carrier wave with the phase shift of 90 degrees. This separates the wave into two bits. Additionally, this will invert all peaks to a positive value or negative, depending on the phase further separating the values. Both the waves go through a filter to remove noise. After being filtered, both bits go through a switch. If the remaining data value is above 0, this will produce a 1. While if the remaining data value is below 0 this will produce a 0. Both bits are then combined and serialised.



Schematic No.3

RESULTS

	NOISE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE		Average
ASK	0	0%	0%	0%	0%	0%		0%
	-5	0%	2%	2%	0%	2%		1%
	-10	10%	8%	10%	10%	11%		10%
	-15	30%	21%	23%	23%	23%		24%
	-20	38%	41%	34%	43%	30%		37%
	-25	33%	46%	43%	38%	56%		43%
	-30	48%	41%	43%	44%	42%		44%
	-35	43%	38%	33%	56%	48%		44%
	-40	53%	53%	53%	51%	56%		53%
	-45	62%	61%	46%	38%	53%		52%
	NOISE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE		Average
PSK	0	0%	0%	0%	0%	0%		0%
	-5	0%	0%	0%	0%	0%		0%
	-10	7%	3%	0%	3%	3%		3%
	-15	8%	10%	10%	11%	10%		10%
	-20	16%	15%	25%	28%	15%		20%
	-25	33%	33%	36%	38%	43%		37%
	-30	41%	48%	35%	48%	31%		41%
	-35	49%	41%	51%	49%	36%		45%
	-40	49%	46%	51%	44%	38%		46%
	-45	48%	40%	44%	53%	51%		47%
	-50	40%	53%	44%	49%	40%		45%
	-55	44%	41%	43%	53%	54%		47%
	-60	53%	57%	49%	52%	59%		54%
	-65	41%	52%	56%	61%	53%		53%
	NOISE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE	PERCENTAGE		Average
QPSK	0	0%	0%	0%	0%	0%		0%
	-5	0%	0%	0%	0%	0%		0%
	-10	2%	4%	2%	2%	2%		2%
	-15	5%	9%	0%	5%	9%		6%
	-20	14%	23%	26%	25%	23%		22%
	-25	37%	30%	33%	35%	26%		32%
	-30	58%	35%	42%	40%	39%		43%
	-35	46%	53%	40%	50%	40%		46%
	-40	44%	51%	46%	61%	40%		48%
	-45	53%	47%	47%	49%	46%		48%
	-50	47%	46%	53%	51%	56%		51%
	-55	40%	70%	49%	51%	44%		51%

Table No.1

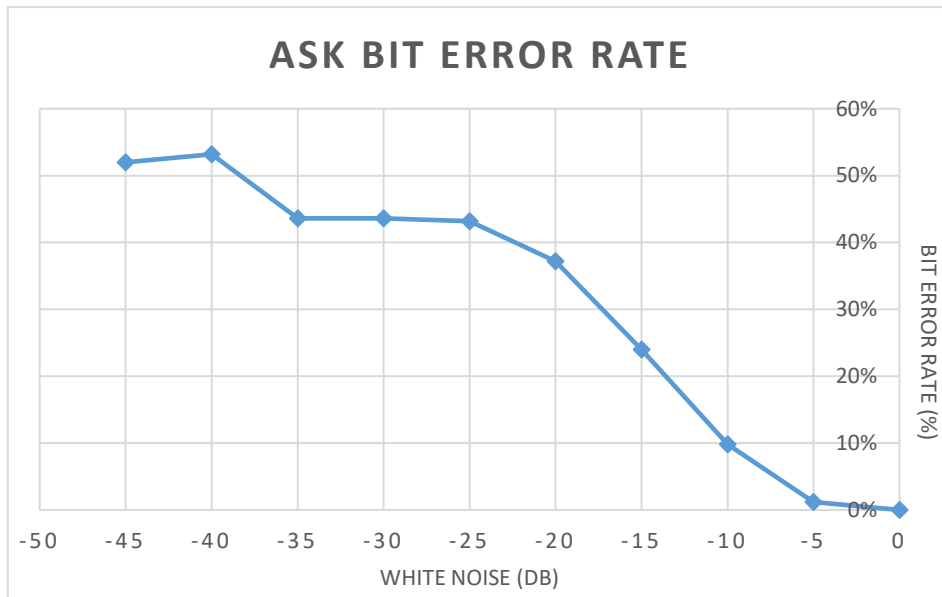


Figure No.9

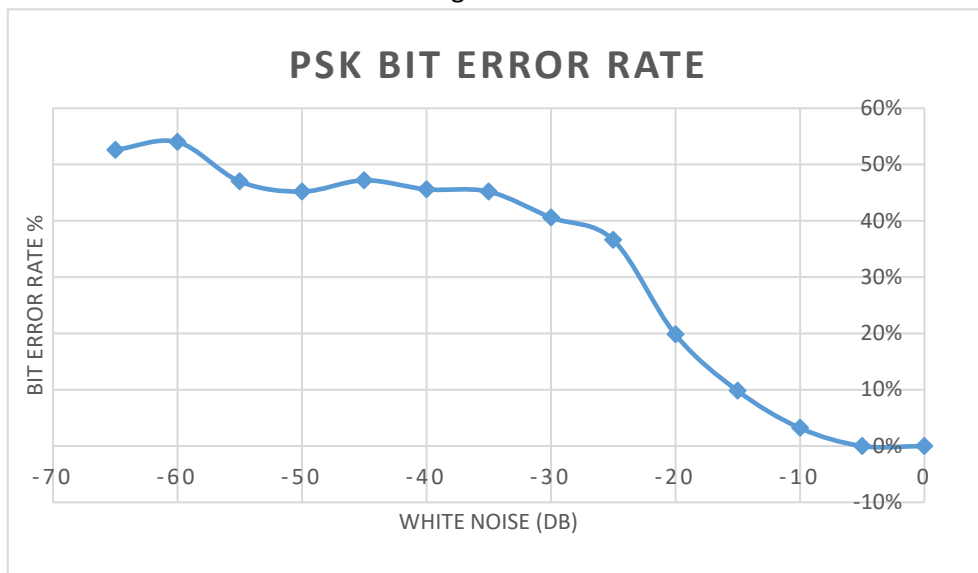


Figure No.10

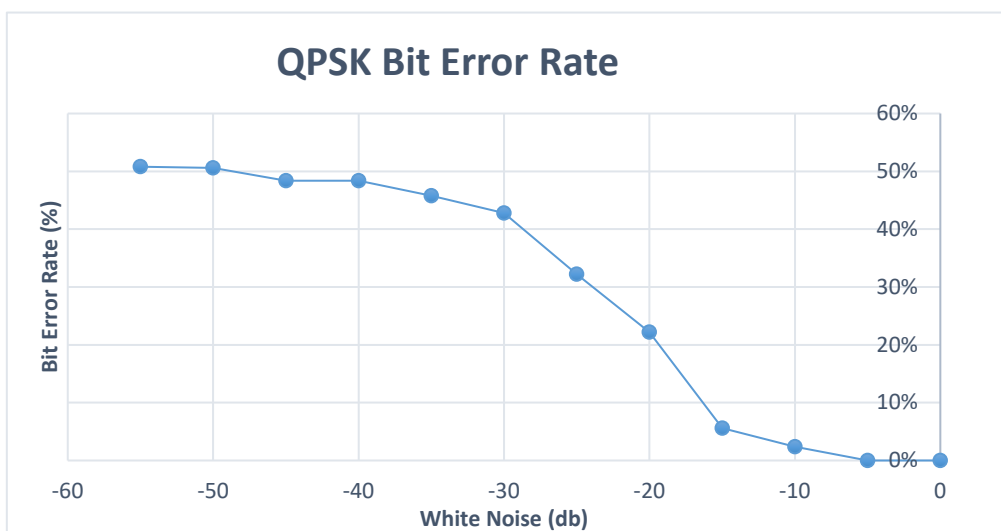


Figure No.11

Discussion

Amplitude Shift Key

ASK reached the 50% bit error rate (BER) at -38db, however at -40db and -45db the BER remained around -52%. This could be because only two different symbols are being transmitted. The symbol has a 50% chance of being correct, even with noise being added.

When comparing ASK to PSK and QPSK it can be seen ASK has higher BER for each decibel, excluding starting point of 0db. This could be a result from the constellation of ASK. The threshold for ASK is closer than the thresholds for PSK and QPSK. When noise is added this can increase the amplitude of the signal being passed. Despite no wave being transmitted, the demodulator could be picking up background noise as the signal. Therefore, ASK should not be used in noisy environments else the demodulator will pick up the noise and convert the noise into symbols.

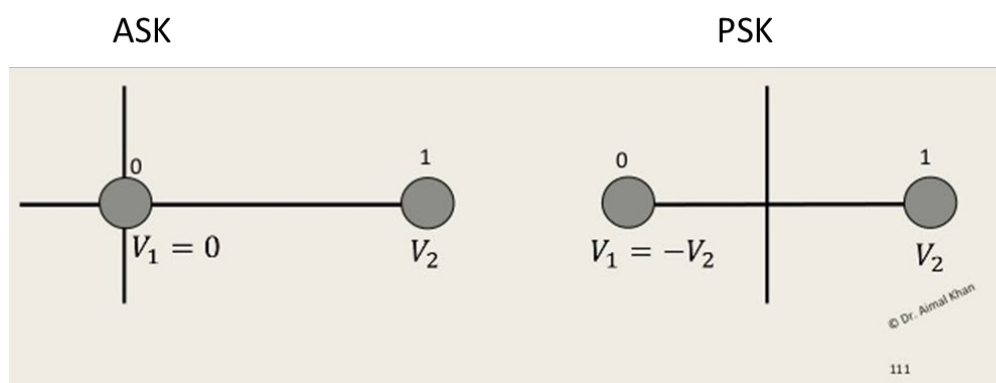


Figure No.12 [17]

Phase Shift Key

PSK reached the 50% BER at 57db. However, at ranges -30db and -55db the BER related and only gradually increased between 40% - 47%. From this data the BER threshold for each circuit should be lowered for further experiments. This is because at larger noise levels the data is largely unaffected due to the 50% chance of being correct or incorrect as a result of binary. This will then improve future designs of digital modulation ensuring faster transmission of correct data.

At lower noise setting (0-20db) PSK, has a lower BER than ASK. This is due to the phase shift used to distinguish between symbols. As a result the threshold between the two symbols are larger, making it more difficult for noise to effect the amplitude. However, by transferring data using phase shifts to demodulate the data is more difficult.

Quadrature Phase Shift Key

QPSK reached 50%-bit error rate at -47db, being the 2nd most resistant to noise. However, at lower noise levels QPSK had lower bit error percentage compared to PSK and ASK until -20db. This could be a result of the quadrature positions of the constellations graphs. The four different phase shifts increasing the difficulty for white noise to cross the threshold to produce a different symbol.

At -30db the BER was 40% while at -50db the BER reached 50%. This is at 10% increase for -20db. These results are behaving very similar to PSK. However, BER has four different combinations compared to two. Therefore, having a lower chance of being randomly correct. It could be argued this data is showing that out of the 2bits being sent every symbol only 1 bit is correct. Going back to the binary bit having a 50% chance of being correct or not. This would then explain why there is no rapid increase of BER at larger noise levels.

Conclusion

In conclusion from the results ASK digital modulation method reached a 50%-bit error rate at -39db while PSK -57db and QPSK -50db.

ASK is the least resistant to noise at all levels, excluding zero due to the tight tolerance that can be seen in the constellation. However, ASK is more affordable and accessible to use. In environments with no noise, such as the visible light spectrum, ASK could be used. For example LED transmitters and optical cables.

QPSK has the best resistance to lower levels of noise. Additionally, it can send two bits of data per every symbol. However, to this circuit is difficult to create and problems can occur with the demodulator and modulator being out of synch. While PSK did obtain a higher noise level, QPSK achieved similar results but has the advantage of sending two pieces of data per every symbol. Allowing faster transmission rates.

Finally PSK has the highest resistance to noise at greater levels, while at lower noise levels (-19db – 0db) is less resistant to noise than QPSK. This is due to the constellation when the two symbols are further apart due to the phase shift. PSK is more energy efficient than ASK.

Further research retest the samples with smaller steps and have a BER threshold of 20%. This would then allow further investigation on the effect noise has on these digital modulation methods while still being able to obtain data from the transmission.

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