DATA TRANSMISSION USING HIERARCHICAL MODULATION OVER A MOBILE WIRELESS CHANNEL

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Approval of the Electrical and Electronic Engineering Department

Prof. Dr. Aykut HOCANIN
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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in cope and quality, as an Undergraduate Project.

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ABSTRACT

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by

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Keywords: Wireless Communications, Hierarchical modulation, QAM, PSK, Rayleigh fading , Eb/No, BER, Median filtering ,Compressed video

This project is about the modeling and simulation of data transmission (picture or video) ,using hierarchical modulation over a mobile wireless channel characterized by Rayleigh fading, Additive White Gaussian Noise (AWGN) and shadowing with two-Antenna diversity selection for system improvement. The objectives are to determine which modulation technique will be best suitable- Quadrature Amplitude Modulation (QAM) or Phase Shift Keying(PSK), the maximum level of modulation as well as switching decisions that will meet the Bit Error Rate (BER) target of 10^{-3},and choosing between uncompressed and compressed transmission of data(images or video) through the channel. The entire modelling and simulation is done using Matlab and Simulink software. Result shows QAM's poor performance and irreducible bit error rate, and extremely great distortion when compressed data is being transmitted. From the result, conclusions can be drawn that PSK performs better than QAM over the channel and that uncompressed data transmission over the channel is better in terms of error sensitivity and since uncompressed images and video was able to be enhanced appreciably using median filtering.

Acknowledgements

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1. INTRODUCTION

Imagine sending a video or picture while driving slowly in an urban city with lots of people, trees and objects around. What would happen to your transmitted data? Definitely some bits sent would be corrupted (be in error). This project tries to simulate data transmission in an environment or scenario similar to what was described at the beginning. Data is transmitted using Hierarchical modulation in a mobile wireless channel.

Our channel is characterized by noise entering the receiver modelled as Additive White Gaussian Noise(AWGN), Slow and flat fading which is modelled as Rayleigh fading and shadowing which is caused by clutters(dense objects, trees, etc.) in the wireless environment. Flat fading is due to multipath when multiple version of the transmitted signal arrives at the receiver possibly due to reflection, diffraction or scattering [1]. To improve system performance, two antenna-diversity selection is also employed, meaning that the receiver uses two antennas for reception and selects the best signal power.

The communication system in this project uses Hierarchical modulation; this implies that our receiver switches from one level of information per modulation symbol to another depending on the channel conditions [2]. For example, a receiver switching from 16-QAM to 4-QAM when the channel condition is bad. The receiver would switch from one level of information per modulation symbol to keep the bit-error-rate less than the target bit error rate which is 10^{-3}. The consequence of switching to lower level of information per modulation symbol is the lowering of the image or video quality (resolution). Many different techniques exist to generate a layered video bit stream. The most common types are known as temporal layering, spatial layering and signal-to-noise-ratio (SNR) layering [3]. In this project spatial layering is considered, which has to do with layering the video bit stream for variable resolution reception (implying variable level of modulation). For example, when the receiver would switch from 16QAM to 4QAM the video quality may degrade in resolution from 720pixels to 240pixels.

The objectives of the project are to compare two modulation techniques for hierarchical modulation, and Quadrature Amplitude Modulation (QAM) and Phase Shift Keying (PSK) are considered. Which performs better in terms of Signal-to-Noise ratio (Eb/No) against Bit-error-rate? Another objective is to determine the maximum level of modulation that can be used considering practical Signal-to-Noise ratio up to 25dB and a target bit error rate of 10^{-3}. Another objective is to design and decide when the Hierarchical receiver is to switch to another level of modulation depending on the channel conditions and finally to model, simulate and compare uncompressed and compressed data transmission over the channel.

This whole project is done in Matlab and Simulink software. The components of the communication system will be modeled and designed using the communication block set of Simulink, and the system will be simulated. From the simulation, the performance plot which is the Signal-to-noise ratio (Eb/No) against Bit-error-rate will be obtained. The transmission of both uncompressed and compressed pictures and video through the system will be simulated and a technique to enhance the uncompressed video and pictures will be found. *Figure 1* shows a summary of the entire modelling and simulation done.

In this project simulation, It is assumed that the receiver has switched and is receiving at a particular level of modulation, so the transmission of video at various levels of modulation is simulated. Due to the complexity of simulating large data, variations in image and video resolution that are arises from the various levels of modulation is ignored. This does not matter much because bit error rate is independent of resolution. So the noise to picture ratio will roughly be the same irrespective of the resolution.

From the simulation and analysis one can conclude that Phase Shift Keying performs far better than Quadrature Amplitude Modulation over the channel and the maximum level of modulation that meet the target BER of 10^{-3} is 32-PSK. Also that compressed transmission is highly sensitive to errors and even propagative in compressed video, and that a received uncompressed noisy picture or video could be enhanced using median filtering.

The remainder of this project report is as follows: in chapter 2 I would describe the channels impairments in details and the model used for each of them and also the model for two antenna diversity. In chapter 3, I will use Quadrature amplitude modulation QAM for hierarchical modulation, simulate it and display the results. In chapter 4, I will use Phase Shift Keying PSK for hierarchical modulation, simulate it and display the results. In chapter 5, we simulate both uncompressed and compressed transmission of pictures and video. Then in chapter later chapter draw conclusions and further discussions on the results and Engineering Standards.

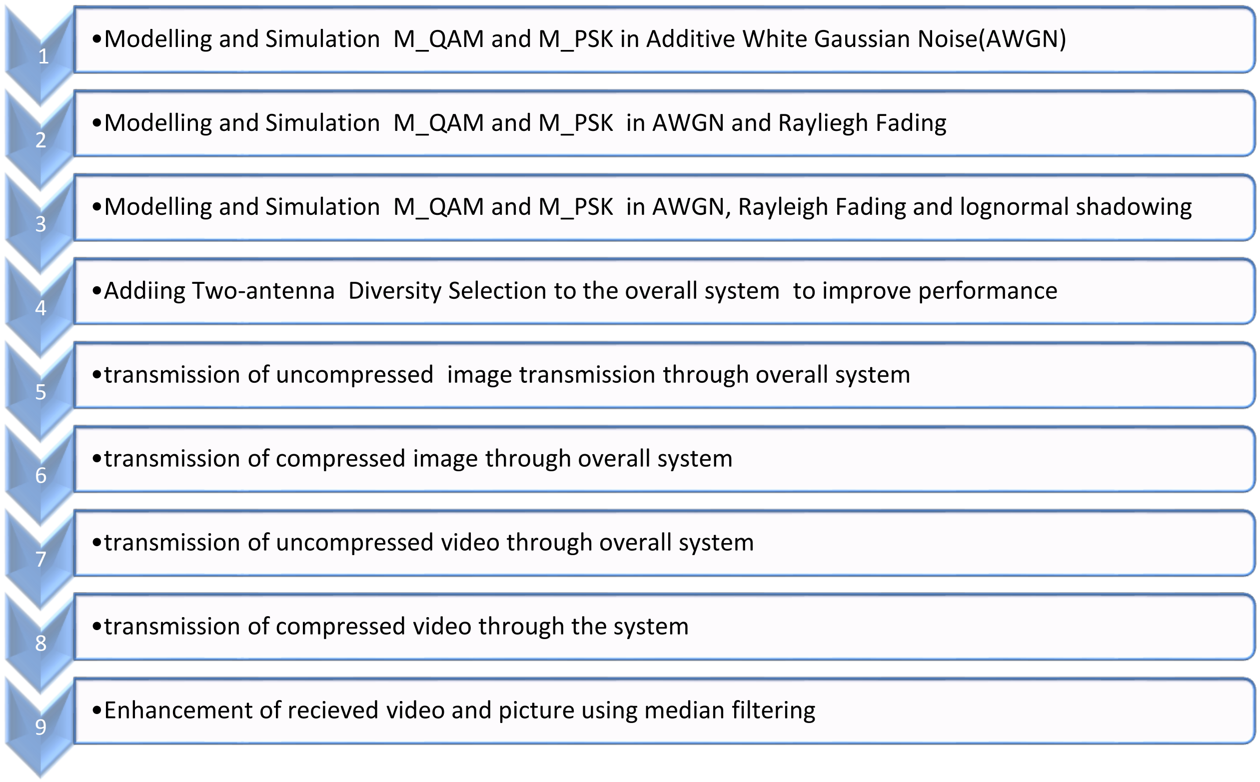

Figure1.1. Summary of the Modelling and Simulations done in the Project.

2. THE MOBILE WIRELESS CHANNEL AND ANTENNA DIVERSITY

In this chapter the entire communication channel is described and the models used in the project are shown as well as their parameters. The channel characteristics (impairments) are noise at the receiver, slow and flat fading modelled as Rayleigh fading and shadowing modelled as lognormal shadowing. Two -Antenna diversity is also added for system improvement.

2.1 Additive White Gaussian Noise (AWGN)

All Electronic component generate thermal noise and hence contribute to the noise level seen a receiver output [4]. The noise along with other minor noise sources is modelled as additive, which implies that the noise is added on the signal, it also modelled as 'white' meaning the noise has a constant power spectral density at all frequencies. Obviously, noise is random process and it is taken to be a Gaussian distributed, where the variance of the Gaussian probability function is essentially the noise power, hence the name Additive White Gaussian Noise.

The received signal power decreases as the distance from the transmitter decreases this implies that the Signal-to-Noise ratio will also decrease as distance from the transmitter decreases since the noise floor is constant. The Signal-to-noise ratio is an important parameter and is related to the probability of bits having errors (bit error rate). Throughout this project signal-to-noise is taken to be Eb/No which is Energy per bit to Noise Energy. Practical Eb/No for receiver distances of a hundreds of meters to a few kilometers for a typical mobile transmitted signal power is up to 25dB. Throughout the project the simulations up to 24dB Signal to Noise ratio (Eb/No) is simulated.

The Simulink Communication block set has an AWGN channel block and parameter settings as shown in *Figure 2.1*.

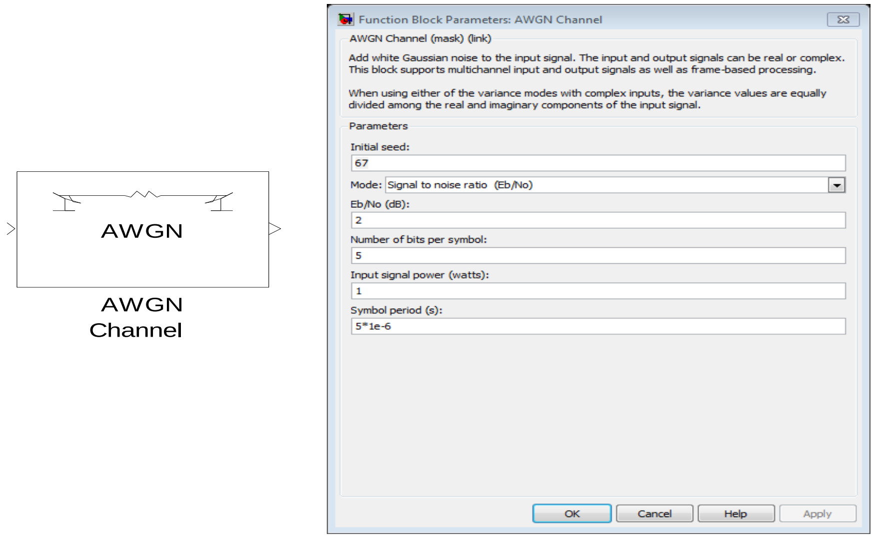

Figure 2.1: Simulink AWGN Channel model block and Parameters

2.2 Rayleigh Fading

In a wireless environment, reflection, diffraction and scattering occurs, this leads to multipath. Multiple versions of the received signal arriving at different times leads to time dispersion of the received signal, In this project only flat fading is considered. Flat fading implies that the delay spread σ_t of the received signal is much less than the symbol period of the signal T_S.

$$\sigma_t \ll T_S \tag{2.1}$$

Also our receiver is mobile, this means our receiver could be moving at a particular velocity *v* this gives rise to Doppler shift (in frequency). The maximum Doppler frequency is given by [6] :

$$f_m = \frac{v}{\lambda} \tag{2.2}$$

Where λ is the wavelength of the carrier wave. The coherence time Tc

$$Tc \approx \frac{1}{f_m} \tag{2.3}$$

Here in this project only Slow fading is considered which means the channel variations(coherence time T*c*) is much slower than the signal symbol period T_s

$$T_s \ll T_c \tag{2.4}$$

Both flat and slow fading could be modelled having a Rayleigh distribution given by:

$$\begin{cases} \frac{r}{\sigma^2} exp\left[-\frac{r^2}{2\sigma^2}\right] & for\ r \geq 0 \\ 0 & elswhere \end{cases} \tag{2.5}$$

The Rayleigh channel model is used when there is no line of sight (NLOS) between the receiver and the transmitter. The Rayleigh Fading Channel Model is also available in the Simulink communication block set. *Figure 2.2*, shows the model of the Rayleigh fading Channel.

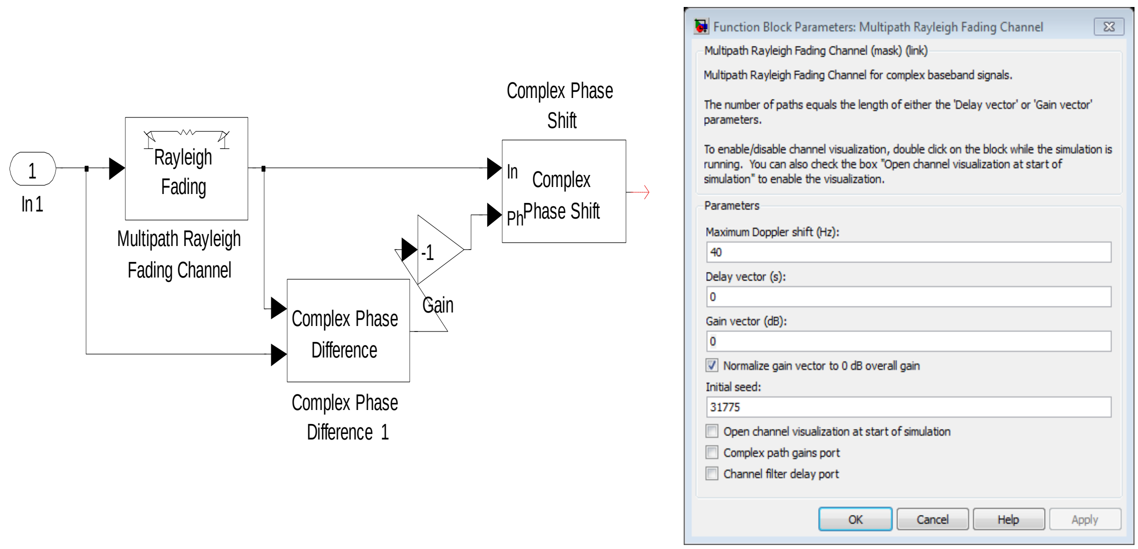

Figure 2.2: Simulink Multipath Rayleigh Fading channel and parameters

2.3 Lognormal Shadowing

Shadowing is the effect that the received signal power fluctuates due to object obstructing the propagation path between the transmitter and receiver [5]. To model this effect, the power is first in their logarithmic values 'log' and it is modelled to be 'normally' (Gaussian) distributed about the mean power, hence the name Lognormal Shadowing. Lognormal shadowing can be best described by [4]:

$$L_p(d)\ (\text{dB}) = L_s(d_0)\ (\text{dB}) + 10n\log_{10}(d/d_0) + X_\sigma\ (\text{dB}) \tag{2.6}$$

X_σ is the random and fluctuating part, where σ is the standard deviation of over the mean power. The '$L_s(d_0)$ (dB) + $10n\log_{10}(d/d_0)$' part is already embedded within the Signal to Noise ratio (Eb/No). The standard deviation σ is also known as the shadowing depth.

In this project we consider Small area shadowing over distances ranging about hundreds of meters, from [5] the maximum practical Small area shadowing depth experienced is about 7dB and in this project, shadowing depths up to 7dB is simulated.

I modelled a shadowing channel using basic blocks of Simulink. The Gaussian random generator was set to be in dB and then back converted to normal values, this is then multiplied to signal power which is also in normal values (multiplication is addition in dB). Figure 2.3 shows the designed model.

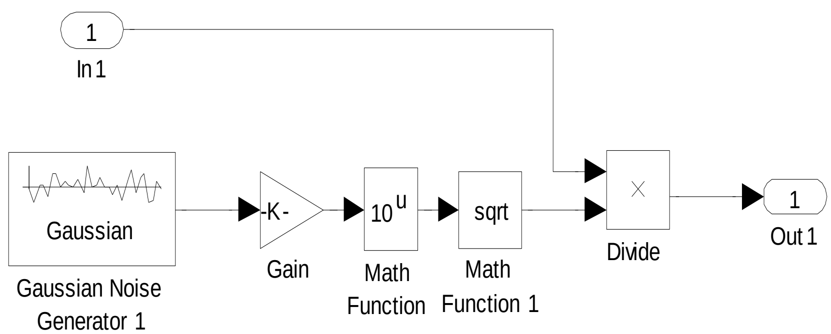

Figure 2.3: Simulink Lognormal shadowing Channel

2.4 Two- Antenna Diversity Selection

One cost way efficient of improving the system performance is the use of two-antenna at the receiver and selecting the best signal quality between the two (this is called antenna diversity) . The antennas are assumed to physically separated by about half the wavelength of the carrier to ensure statistical independency, this is so that if one signal undergoes into deep fade the other would most likely have as a strong signal [1].

In the Simulation, the antenna diversity is modelled as shown in Figure 2.4. The model was designed using logical operations blocks to basically find the maximum of two received signal, as the transmitted signal is transmitted through two independent communication channels to serve as a model for the receiver receiving two rays(one for each antenna).

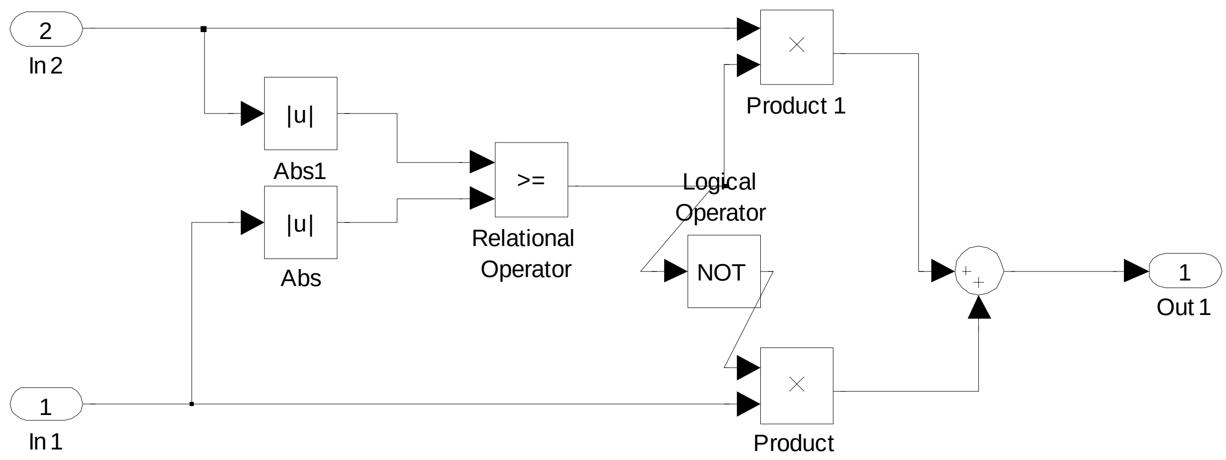

Figure 2.4: Simulink Two-Antenna diversity Model

3. USING QUADRATURE AMPLITUDE MODULATION (QAM) FOR HIERARCHICAL MODULATION

In this chapter, Quadrature Amplitude Modulation QAM is used for hierarchical modulation and the performance is evaluated, results and observations are shown.

3.1 Quadrature Amplitude Modulation QAM

Quadrature Amplitude Modulation is a multilevel modulation technique where information is stored on both the amplitude and the phase. A QAM signal is given by:

$$s_i(t) = I_i(t)\cos(2\pi f_c t) - Q_i(t)\sin(2\pi f_c t) \qquad (3.1)$$

Where i= 1,2,3…M ; f_c is the carrier frequency and I_i and Q_i are the in phase and quadrature components.

The numbers of level $M = 2^l$ where l is the number of bits in a symbol [4]. Typical levels of QAM could be 4QAM, 16QAM, 64QAM corresponding to 2bits 4bits and 6bits per symbol respectively. The advantage of higher levels of modulation is that the system can have higher transmission rates for roughly the same transmission bandwidth, hence spectrally efficient. The relationship between transmission bandwidth B_T and bit rate R for QAM is given by [6]:

$$R = \frac{l * B_T}{2} \qquad (3.2)$$

Figure 3.1 shows typical QAM constellation diagram. In this project rectangular QAM is used meaning the constellation diagram is rectangular in shape.

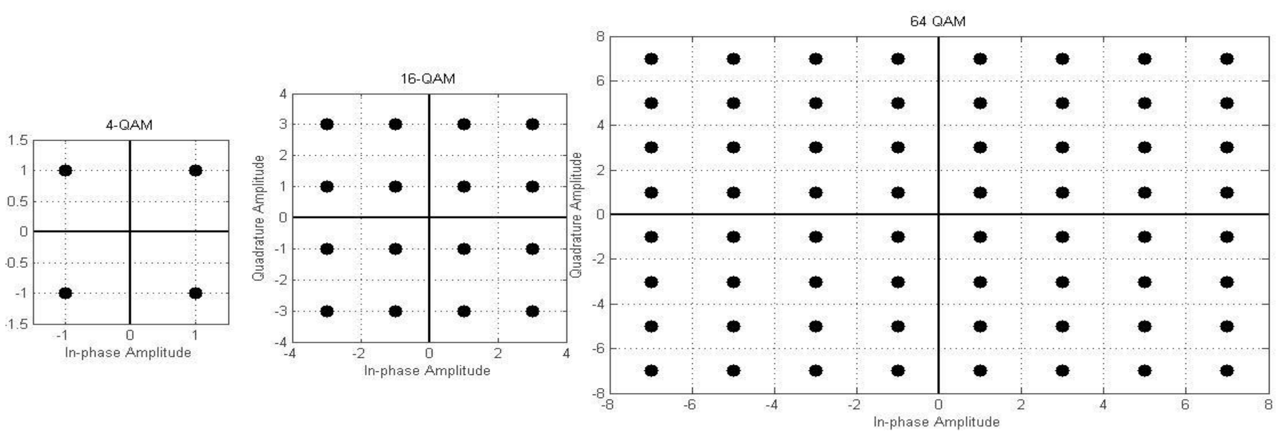

Figure 3.1: QAM constellation diagram a)4QAM b)16QAM c)64QAM

3.2 Simulation of QAM over the channel

Quadrature Amplitude Modulation is simulated over the channel characterized by Additive White Gaussian noise, Rayleigh fading and two- antenna diversity for channel improvement. Shadowing which causes further impairment is not included yet.

In this project simulation, It is assumed that the receiver has switched and is receiving at a particular level of modulation, so various levels of modulation is simulated. 4QAM, 16QAM and 64QAM is simulated. *Figure 3.2* shows the simulation block diagram. Random bits are being generated by a Bernoulli binary generator and then transmitted using 4QAM, 16QAM and 64QAM over the channel. At various Signal-to-Noise ratio (Eb/No) up to 24dB, the bit error rate is then computed during the simulation. Table 3.1 shows some simulation parameter settings.

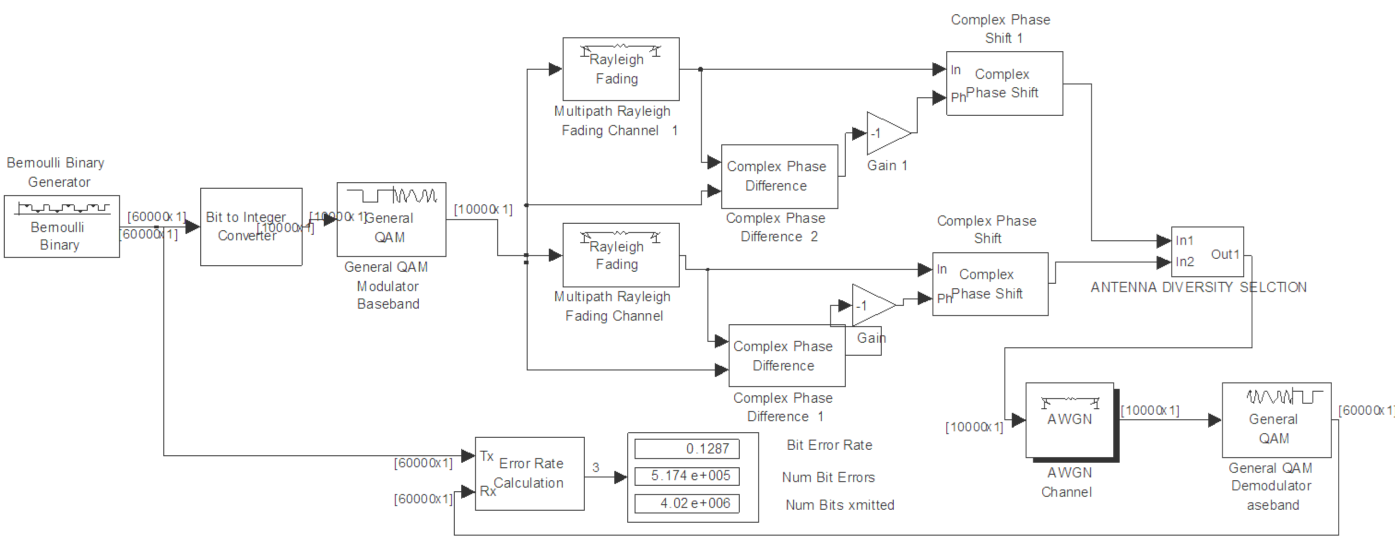

Figure 3.2: Simulink Block diagram of QAM in AWGN and Rayleigh Fading with two-antenna diversity

QAM simulated	4-QAM, 16-QAM, 64QAM
Signal to Noise Ratio (Eb/No) range	0 – 25dB
Maximum Doppler Shift	40Hz
Simulation stop time	4s
Sample time	1e-6s

Table 3.1: QAM simulation Parameter settings.

3.3 Performance Results of QAM over the Channel

Figure 3.3 Shows the results of the entire simulation. From the results it can be observed that 4QAM meets the bit error rate target BER of 10^{-3} at a Signal-to-Noise ratio (Eb/No) of 13dB, but all levels of modulation higher than 4QAM are unable to meet the BER target of 10^{-3} at any Eb/No. 16QAM experiences an irreducible BER of 0.04 and 64QAM experiences and irreducible BER of 0.12.

This results shows that QAM cannot be used for hierarchical modulation over the specified channel, since the receiver cannot use higher levels of modulation as they all fail to meet a reasonable BER target of 10^{-3}.

My explanation for the occurrence of its poor performance and irreducible bit error experienced at levels of modulation higher than 4QAM is that, QAM stores some information in the amplitude and there will be random variations in amplitude caused by Rayleigh fading, so irrespective of the level the additive white Gaussian noise occurring at the receiver [Signal-to - Noise] the bit error rate cannot go below a certain level.

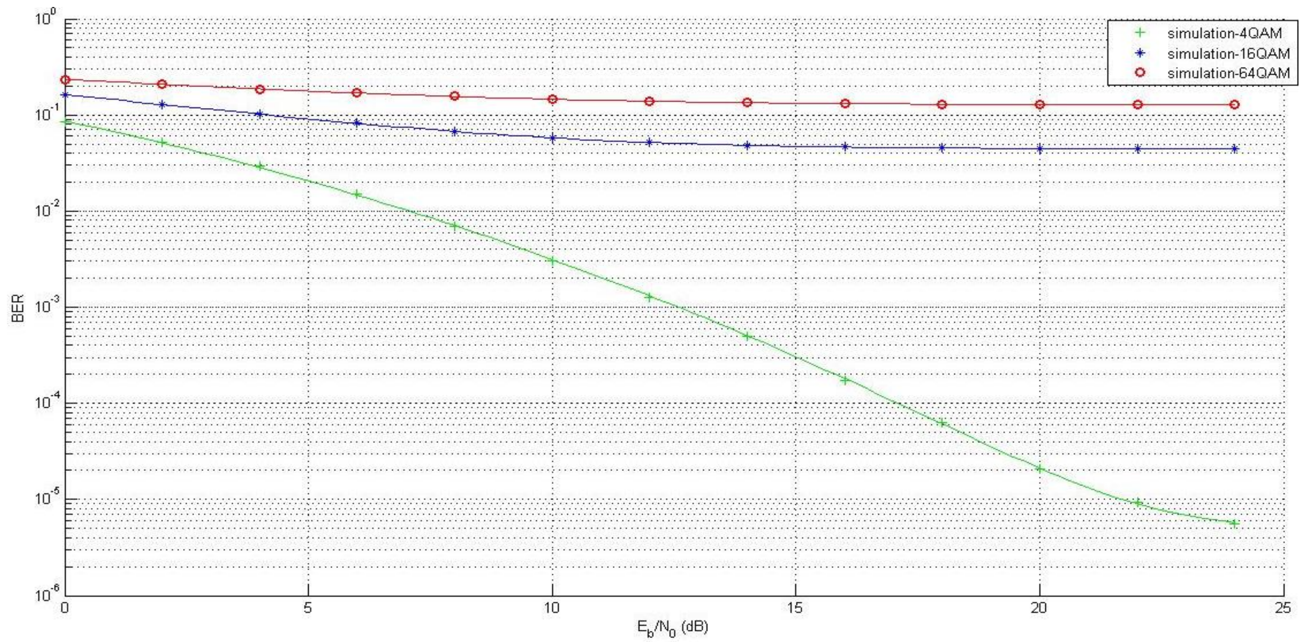

Figure 3.3: Performance Plot of QAM in AWGN and Rayleigh fading channel with two-antenna diversity

4. USING M-ARY PHASE KEYING (PSK) FOR HIERARCHICAL MODULATION

4.1 M-ARY PHASE SHIFT KEYING

M-ary Phase shift keying PSK is a multilevel modulation technique that stores information only in the phase of the carrier unlike QAM which stores on both amplitude and phase. An M-ary signal could be represented by [7]:

$$S_i = A\cos(2\pi f_c t + \theta_i) \quad 0 \le t \le T \quad i = 1,2,3 \ldots M \tag{4.1}$$

Where f_c is frequency of the carrier and M is the level of modulation, l is the number of bits in a level of modulation M , $M = 2^l$. Typical M-ary PSKs are 4-PSK, 8-PSK, 16-PSK, 32-PSK which corresponds to 2 bits, 3 bits, 4 bits and 5 bits per modulation symbol respectively.

Figure 4.1 shows 4PSK, 16PSK and 32PSK constellation diagram.

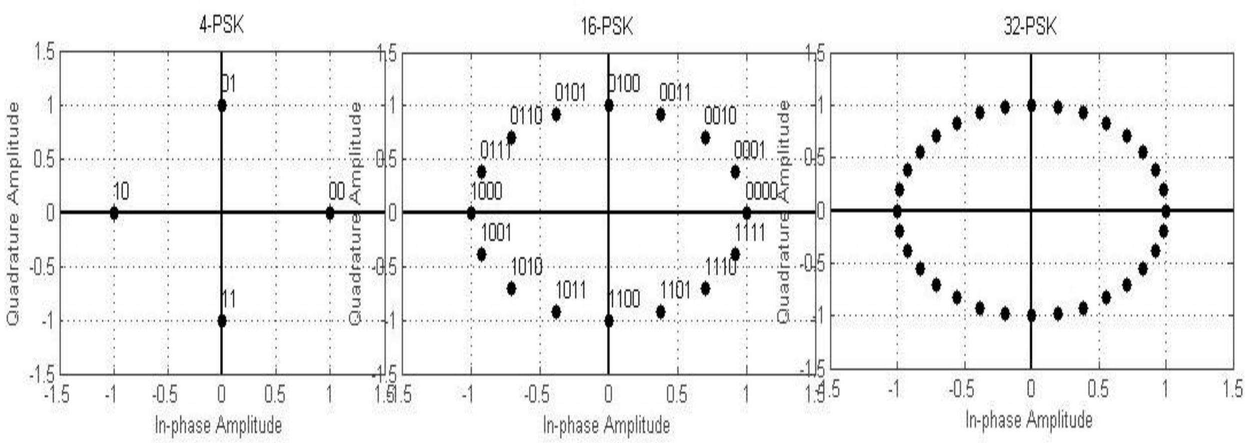

Figure 4.1.M-ary PSK constellation diagram a)4PSK b)16PSK c)32PSK

The advantage of higher levels of modulation is that one can have higher transmission rate with the same bandwidth of transmitting 1bit per modulation symbol. The relationship between the transmission bandwidth and the transmission rate is given by:

$$R = \frac{l * B_T}{2} \tag{4.2}$$

4.2 Simulation of M-ary PSK over the Channel

In this simulation 4PSK, 16PSK, and 32PSK is simulated over the channel, that has AWGN, Rayleigh fading and shadowing. 0dB, 4dB and 7dB shadowing depth are simulated. Recalling that small-area shadowing is considered in this project and has a maximum shadowing depth of 7dB as observed in [5]. *Figure 4.2* shows the simulation block diagram. Table 4.1 shows some simulation parameter settings.

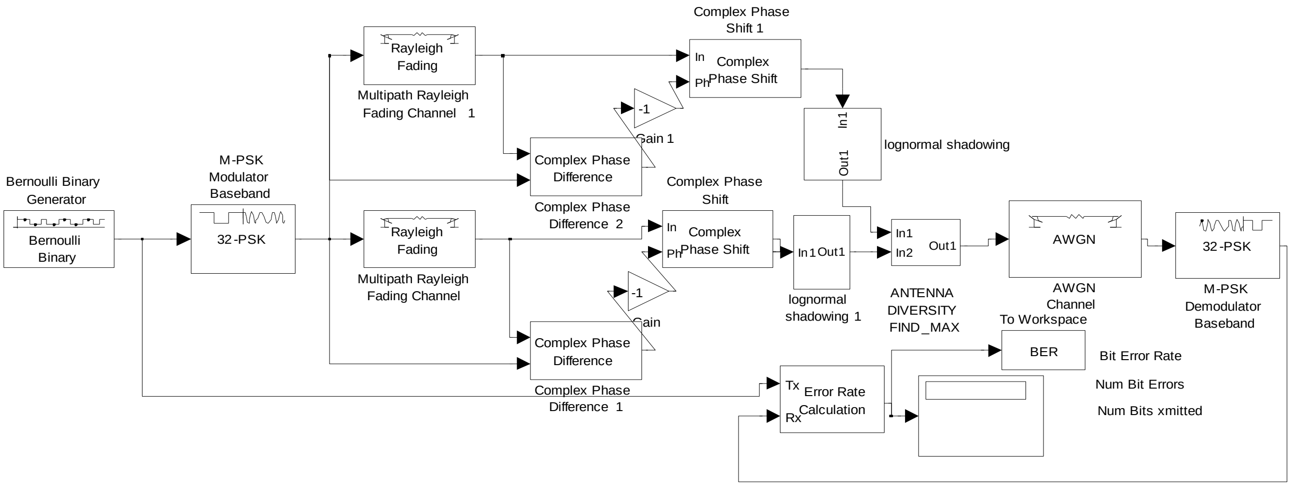

Figure 4.2: Simulink Block diagram of M-ary PSK over AWGN, Rayleigh fading and lognormal shadowing with two-antenna diversity

M-PSK simulated	4-PSK, 16-PSK, 32-PSK
Signal to Noise Ratio (Eb/No) range	0 – 25dB
Maximum Doppler Shift	40Hz
Shadowing depth	0, 4 and 7dB
Simulation stop time	4s
Sample time	1e-6s
Constellation ordering	gray

Table 4.1: M-PSK simulation Parameter settings.

4.3 Results of Simulation of M-ary PSK

Figure 4.3, 4.4 and 4.5 shows the result of the simulation. Figure 4.3, shows result of simulation when shadowing is 0dB(No shadowing) ,Figure 4.4 shows the result of simulation when shadowing is 4dB(medium shadowing), and Figure 4.5 shows the result when shadowing is 7dB(High Shadowing).

It can be observed that unlike Quadrature Amplitude Modulation, M-ary PSK does not experience irreducible bit error rate within the scope of Signal to Noise ratio (Eb/No) up to 25dB. This is as a result of the fact that PSK does not store information on the amplitude so the random amplitude variations caused by the Rayleigh fading has minimal effect on the information stored in the phase.

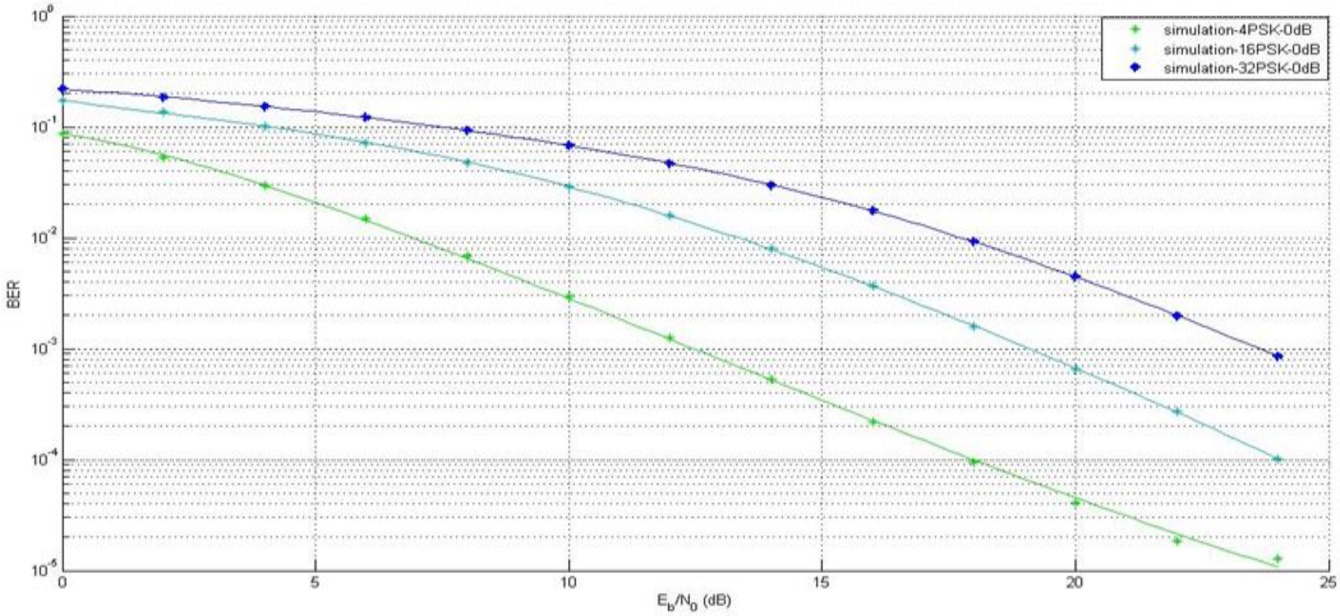

Figure 4.3: Performance of PSK over AWGN , Rayleigh fading at 0dB shadowing

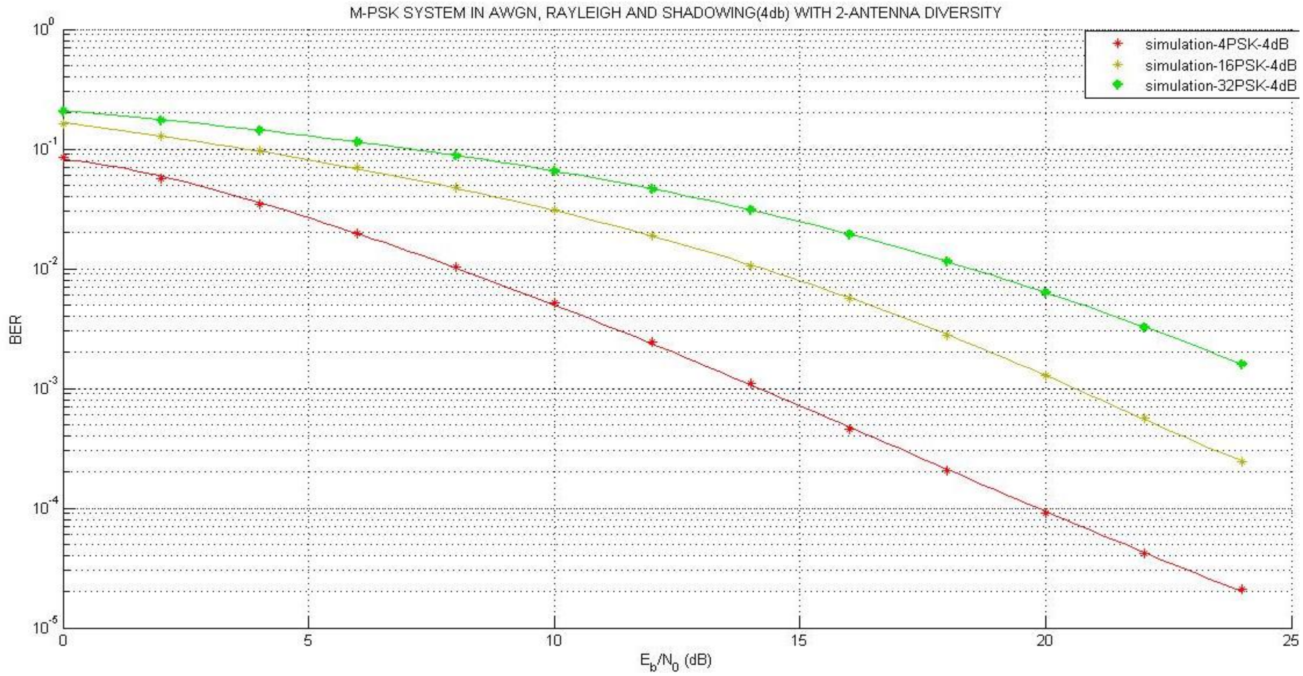

Figure 4.4: Performance of M-PSK over AWGN , Rayleigh fading at 4dB shadowing

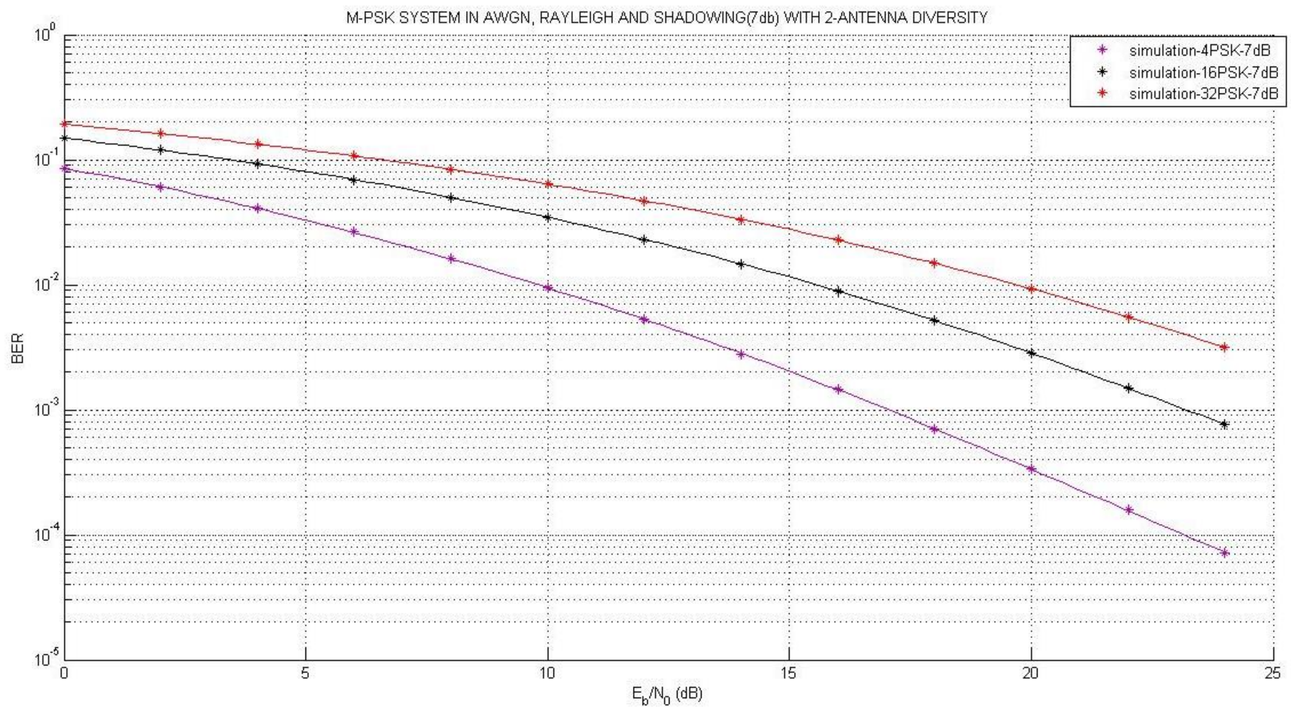

Figure 4.5: Performance of M-PSK over AWGN , Rayleigh fading at 7dB shadowing

It can also be seen from the results that generally, M- PSK meets the bit error target requirement of 10^{-3} at Eb/No less than 25dB. It can also be observed from *Figure 4.3* that above 32-PSK the system will not meet the bit error rate target of 10^{-3} at any Signal-to-Noise ratio less than 25dB. So the Hierarchical modulation system should be designed to up to the maximum of 32-PSK, considering a maximum Eb/No of 25dB so as not to fall below the target bit error rate. Table 4.2 summarizes from the result in *Figure 4.3*, *Figure 4.4* and *Figure 4.5*, the Signal to Noise ratio at which the bit error rate target of 10^{-3} is met for 4PSK, 16PSK and 32PSK at 0db shadowing depth, 4dB shadowing depth and 7dB shadowing depth.

	Minimum Eb/No (dB) that meets 10^{-3} for Level of Modulation *M*		
Shadowing depth(dB)	4-PSK	16-PSK	32-PSK
0	12	19	24
4	14	20	25
7	16	22	27

Table 4.2 Minimum Eb/No at various M-PSK and Shadowing Depth at BER 10^{-3}

4.4 Designing Hierarchical Receiver Switching Conditions

From Table 4.2 switching conditions for the hierarchical receiver to decide when to switch can be derived. The receiver needs only to have a Signal power estimator and take the running standard deviation to obtain both Signal-to-noise ratio and shadowing depth.

When there is no shadowing (shadowing depth 0 dB) :

If Eb/No < 19dB receiver should receiving with 4PSK

If 19dB <Eb/No < 24dB receiver should switch to 16PSK

If Eb/No > 24dB receiver 32PSK

Similarly, for shadowing depth 4dB and 7dB the switching decision could be derived from *table 4.2* in a similar manner.

As the receiver switches from one level of modulation to another, it will loose some bit/per symbol. Since the transmitted data picture or video is layered in bits, it will only mean losing some layers which will in turn result into lower picture or video resolution since the picture or video is spatially layered. For example the video stream of picture is layered into 5 layers of bit stream, M= 2^5 =32PK, If the receiver switches to 16PSK it can only receive 4 layers,(2^4 =16PSK).

5. IMAGE AND VIDEO TRANSMISSION OVER THE CHANNEL

So far, we have seen that QAM performs poorly over the channel and that M-ary PSK meets the target bit error rate of 10^{-3} within Signal-to-Noise ratio (Eb/No) less than 25dB over the channel, So M-ary PSK is now used. Now in this chapter both uncompressed and compressed picture and video transmission over the channel will be simulated and the quality of the received image will be observed.

5.1 Uncompressed Image and video transmission over the channel

The transmission of raw images and videos is simulated, the pixel values in bits are transmitted as they are without compression and the bits (image or video) are received. To begin, the image or video is processed in Matlab into bits and transmitted from the workspace of Matlab into the Simulink Model of the PSK system in AWGN, Rayleigh fading, lognormal shadowing and two-antenna diversity System as in the previous chapter. The received bits are being back to Matlab workspace where the received image or video is being displayed. *Figure 5.1* shows the Simulink model of the entire system in a compact form and the Matlab code for processing the images and videos into bits for transmission could be seen at the *Appendix 10.1* and *10.3* of this report. *Figure 5.2* shows an image transmitted at some channel conditions that has bit error rate of 10^{-3} and *Figure 5.3* shows an image transmitted at some channel conditions below at 10^{-2} which is far below the target bit error rate.

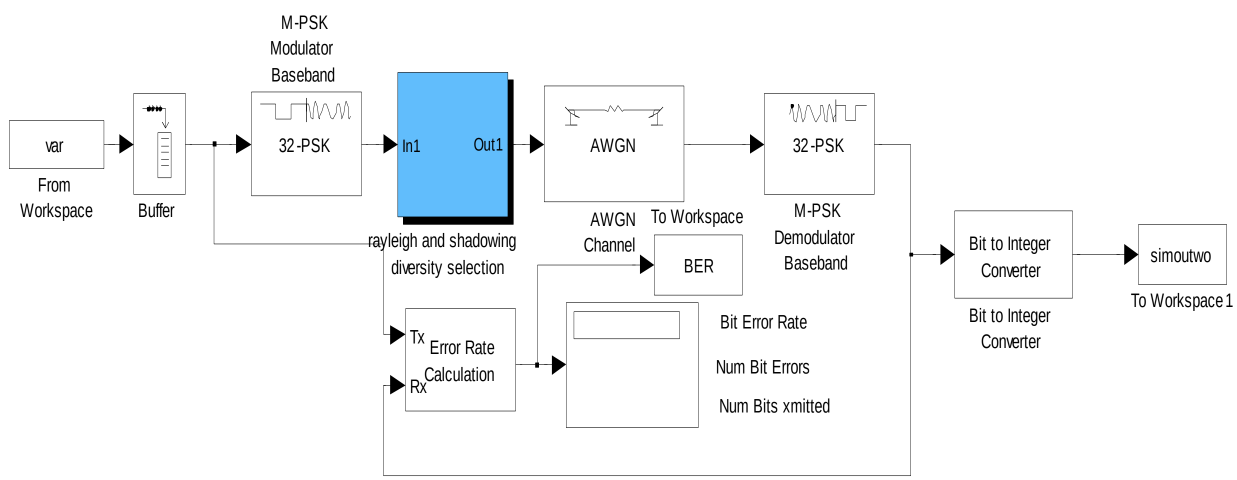

Figure 5.1: Image transmission over AWGN, Rayleigh Fading, Shadowing and two antenna diversity.

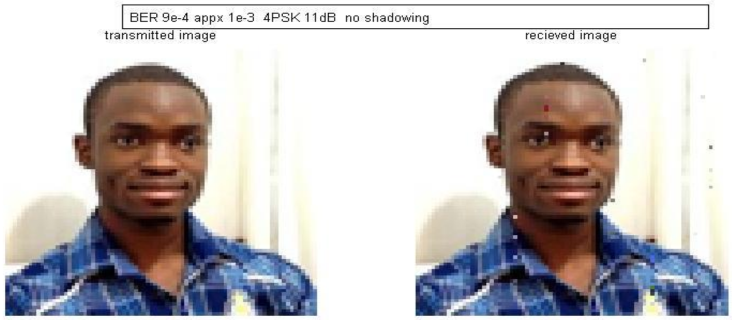

Figure 5.2. Transmitted and received uncompressed image at target

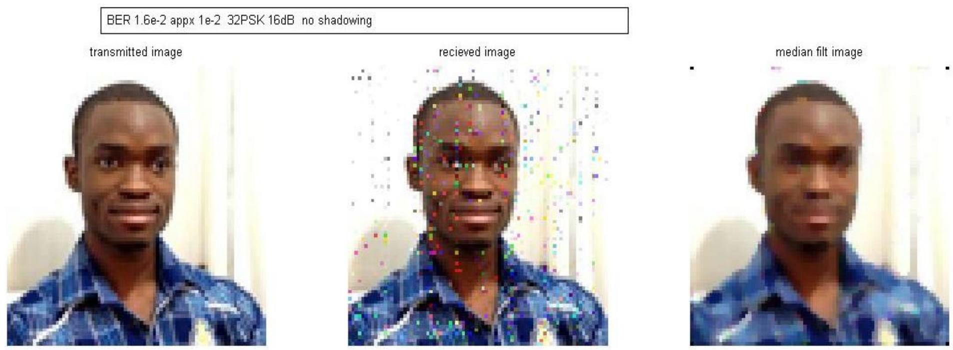

Figure 5.3: Transmitted and Received picture at 10^{-2} and Median filtered received image.

5.2 Enhancement of received uncompressed image and video using Median filtering

What if the channel conditions is so bad that it falls below the Bit error rate goes high as as 10^{-2} as in *Figure 5.3*? Can some Image and video processing be done to enhance the received image? In this project I found out that since the distorted on the received image appears like 'dots', median filtering could be used to smoothen the picture and remove those 'dots'. The median filter selects a 3by3 pixel neighbor-hood throughout the received image or video and takes the median pixel value. *Figure 5.3c* shows the received image after median filtering. The effect of the median filter would be much better if the picture has a higher resolution, for sake of simulation simplicity and 80*80 image was simulated in *Figure 5.3*. Since videos are merely multiple frames of images, median filtering can also applied to the received uncompressed videos that are highly distorted. The Matlab code for median filtering the received video can be seen at *Appendix 10.4*.

5.3 Compressed image and video transmission

Most papers, projects focus more on uncompressed transmission and little is said about transmitting compressed video and images. The transmission of compressed picture (JPEG) and compressed video (AVI) over the channel is simulated using same the communication system. Matlab codes was written by me to process the compressed images and video into a stream of bits and this bits are passed from the workspace of Matlab into the Simulink model where the simulation is done and the received bit is taken out to the Matlab workspace where the image or video can be played(excluding the audio) ,The Matlab codes for processing the compressed images and video into a stream of bits can be seen in *Appendix 10.2* and *10.5*.

For compressed images, when the channel conditions meet the target bit error rate of 10^{-3}, the received image file is very much corrupted by bit errors that file is unable to opened by any image viewing software. Further simulations shows not until a bit error rate of $5*10^{-4}$ before a transmitted image (JPEG) file will be able to open, and not all the times. If it 'luckily' opens the picture are highly distorted and often irritating in appearance. Figure 5.4 shows a transmitted image received at a bit error rate of $5.3*10^{-5}$, only three bits where in error in the entire picture file.

Figure 5.4: A Transmitted and received Compressed lmage .

Furthermore, when compressed video is transmitted over the channel at 5e-5 which is far above our target BER and difficult to attain (see Figure 4.3) the received video is irritating to the eye. I observe that due to predictive coding in the AVI compression and most video compression techniques, when the received video is observed the error propagates through frames that are similar. Figure 5.5 shows one of the frames of a transmitted and received video clip at bit error rate 3.95e-5.

Figure 5.5: A frame of a transmitted and received video over the channel BER 3.95e-5

From the observations and results, Compressed image and video transmission cannot be used over the communication system because within the bit error rate target of 10^{-3}, the received image and video files cannot even open.

5.4 Data (Picture and video) Layering

For Hierarchical modulation, the data stream needs to be layered. In this project Spatial (Resolution) layering is considered. This means that the number of layered received will only change the resolution of the image or video received.

In this project since up to 32-PSK meets the target bit error rate. The system can have 5 layers of picture ($2^5=32$), so that receiving the full 5 layers will mean receiving the maximum resolution, the hierarchical receiver switching down to 16-PSK ($2^4=16$) to meet the bit error rate target would imply a lower image or video resolution. Due to simulation complexity same resolution is assumed while simulating. Appendix 10.6 shows a Matlab code that processes an image in 5 layers of bits, which is then combined together in fives one from each one to form a one large stream of bit.

6. CONCLUSION

In this project, Data transmission using hierarchical modulation over a channel in additive white Gaussian noise (AWGN), Rayleigh fading, lognormal shadowing and two-antenna diversity for system improvement was modelled and simulated. The use of Quadrature Amplitude modulation (QAM) and M-ary Phase Keying (PSK) has been investigated. From the performance results, QAM performs poorly having an irreducible bit error rate far worse than the target bit error rate of 10^{-3} and on the other hand M-ary PSK meets the bit error rate target within the maximum Signal-to-noise ratio limit of 25dB up to 32-PSK. I was able to design a switching table for the hierarchical receiver to make switching decisions. So I conclude the use of M-PSK switching up to 32-PSK for Hierarchical modulation.

In this project, the transmission of uncompressed images and video and compressed ones was compared. We observed that Compressed images(JPEG) and video(AVI) are very sensitive to bit errors, that in compressed images just 3 bits in error in the file would cause heavy distortion to the overall image, and furthermore in compressed video errors propagate through the similar frames due to the predictive coding using in video compression algorithms. At our target bit error rate of 10^{-3} the compressed files are unable to open. In the case of uncompressed images and video at our target bit error rate, the images and video almost still maintain their quality but just with a few ‘dots’ on the image. In addition when the channel conditions fall the target bit error rate, Median filtering was applied to distorted uncompressed image to ‘clean’ the dots.

In conclusion, I have virtually simulated the design of a hierarchical modulation system that switches up to 32-PSK, that allows the transmission of only uncompressed images and video effectively and when the channel conditions fall far below the target it bit error rate of 10^{-3}, median filtering could be used to enhance the distorted image.

7. FUTURE WORK

Further work in the future could be done on this project. Powerful interleaving, concatenated coding like turbo codes or Reed-Solomon/convolutional code alongside with Packetization and Retransmission could be used to ensure perfect transmission so to enable a communication system to the support transmission of compressed videos and images through a channel in additive white Gaussian noise, Rayleigh fading and lognormal-shadowing.

8. ENGINEERING STANDARDS

Most of the parts of the project model components conform to many engineering standards. Currently Hierarchical modulation is used in digital video broadcasting terrestrial DVB-T [2]. Some variants of Digital Video Broadcasting - Satellite - Second Generation (DVB-S2) and some other standards use Phase shift keying(PSK).

The Signal-to-noise ratio considerations of up to 25dB used in this project conform to many mobile wireless systems standard such as 2G and 3G networks.

9. REFERENCES

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10. APPENDIX

10.1

Matlab code for processing uncompressed images into stream of bits to the Simulink model, collecting received bits from the Simulink model and median filtering.

Image_transmit_uncomp.m

```
 clear all

aa=imresize(imread('images1.jpg'),[50 80]);
figure
[rw cl nim]= size(aa);
bersum=0;

%setting some simulation parameters

 xe=16; va=0; ma=5; mnum=2^ma;fsize=80;

 % xe is Eb/No; va is the square of the shadowing depth
 %mum = is the level of modulation

 %transmitting each of the R G B
for i=1:3

 a = aa(:,:,i);
b= reshape(a,(rw*cl),1);
c=dec2bin(b);
zz=c';
x = zz(:);

mm=rw*cl*8;

xw = str2num(x);

var.time = (0:(mm-1))';
var.signals.values = xw;
% passing bit stream to the simulink model for simulation
sim('imagetransmitg')

bersum =bersum + BER(2);
%collecting the receieved bits.
tr= simoutwo.signals.values;
dd(:,:,i)=reshape(tr,rw,cl);
end


% median filtering the image
ddf(:,:,1)=medfilt2(dd(:,:,1));
ddf(:,:,2)=medfilt2(dd(:,:,2));
ddf(:,:,3)=medfilt2(dd(:,:,3));
```

```
%diplaying transmittedm received and median filtered
subplot(1,3,1)
imshow(aa);title('transmitted image');

subplot(1,3,2)
imshow(dd)
title('recieved image')

subplot(1,3,3)
imshow(ddf)
title('median filt image')

% displaying the bit error rate
BER(1)
bersum
```

10.2

Matlab code for processing compressed image (JPEG) into stream of bits to the Simulink model, collecting the received bits from the Simulink model and displaying the resulting images.

Imagecomp.m

```
clear all
figure
fp=fopen('testq.jpg','rb');
 if fp > 0
 ibin=fread(fp,inf,'*uint8');
 fclose(fp);
 whos ibin;
 end

   [z d] = size(ibin)
 s = dec2bin(ibin);
t=s';
w = t(:);

xw=str2num(w);
var.time = (0:(z*8-1))';
var.signals.values = xw;
hj = z*8

 %setting some simulation parameters
 % xe is Eb/No; va is the square of the shadowing depth
 %mum = is the level of modulation
 xe=16; va=0; ma=2; mnum=2^ma;fsize=8;

% passing bit stream to the simulink model for simulation
 sim('imagetransmitcomp')

 %collecting the receieved bits.
tr= simoutwo.signals.values;
ibin=tr;
```

```
 fid=fopen('myfile99.jpg','wb');
fwrite(fid,ibin);
fclose(fid);
A=imread('myfile99.jpg','jpeg');


subplot(1,2,1)
imshow('testq.jpg');
title('transmitted')

subplot(1,2,2)
imshow(A)
title('recieved')

% displaying the bit error rate
BER(1)
```

10.3

Matlab code for processing uncompressed Video into stream of bits to the Simulink model, collecting received bits from the Simulink model.

videotransmit_uncompressed.m

```
clear all
obj=mmreader('yesnoa.avi');
a=read(obj);
frames=get(obj,'numberOfFrames');
for k = 1 : frames-1
I(k).cdata = imresize(a(:,:,:,k),[120 160]);
I(k).colormap = [];
end
xe=18;va=0; ma=4;mnum=2^ma;fsize=120;
 [rw cl nim]= size(I(1).cdata);

for ff = 1 : frames-1


bb = I(ff).cdata;


for i=1:3
 a = bb(:,:,i);
b= reshape(a,(rw*cl),1);
c=dec2bin(b);
zz=c';
x = zz(:);
 mm=rw*cl*8;
for u= 1:mm
if x(u)== 48
xr(u)=0;
else
xr(u)=1;
end
```

```
end

xw=xr';
var.time = (0:(mm-1))';
var.signals.values = xw;

sim('videotransmitg')

tr= simoutwo.signals.values;
dd(:,:,i)=reshape(tr,rw,cl);
end



RC(ff).cdata = dd;
RC(ff).colormap = [];
end

BER(1)

implay(RC)
```

10.4

Matlab code is for median filtering the received video.

medianfiltervideo.m

```
% this code performs median filtering on a video

clear all
obj=mmreader('viptrafficreceived.avi');
a=read(obj);
frames=get(obj,'numberOfFrames');
for k = 1 : frames-1
I(k).cdata = imresize(a(:,:,:,k),[120 160]);
I(k).colormap = [];
end

for k = 1 : frames-1

refilt(k).cdata(:,:,1)= medfilt2(I(k).cdata(:,:,1));
refilt(k).cdata(:,:,2)= medfilt2(I(k).cdata(:,:,2));
refilt(k).cdata(:,:,3)= medfilt2(I(k).cdata(:,:,3));

refilt(k).colormap = [];
end
implay(refilt)
movie2avi(refilt,'viptrafficrecievedfilterd');
```

10.5

Matlab code for processing compressed Video(AVI) into stream of bits to the Simulink model, collecting received bits from the Simulink model and saving the received file.

videotransmittcomp.m

```
clear all
fp=fopen('yesnoa.avi','rb');
 if fp > 0
 ibin=fread(fp,inf,'*uint8');
 fclose(fp);
 end

 xe=27;fb=8;mb=2;mm= 2^mb;va=0;


[z d] = size(ibin)
s = dec2bin(ibin);
t=s';
w = t(:);


for cc = 0:68
    xq( (cc*1e5 +1) : ((cc+1)*1e5 )) = str2num( w( (cc*1e5 +1) : ((cc+1)*1e5
)) );
end
xq( (69*1e5+1) : length(w) ) = str2num( w( (69*1e5+1) : length(w) ) );
xw = xq';

var.time = (0:(z*8- 1))';
var.signals.values = xw;
hj = z*8

sim('videotransmitcomp')
tr= simoutwo.signals.values;
ibin=tr;

fid=fopen('myfile4.avi','wb'); fwrite(fid,ibin); fclose(fid);


BER(1)
```

10.6

This Matlab code processes an image in 5 layers of bits, which is then combined together in fives one from each one to form a one large stream of bit.

Layered5.m

```
clear all
I = imread('lena.jpg');
I =  imresize(imread('lena.jpg'), [100 100]);

% forming five layers spatially (resolution)
i1= reshape(I,1,10000);
n1= 1:10000/5;
r1(n1)=i1(5*n1);
r2(n1)=i1(5*n1-1);
r3(n1)=i1(5*n1-2);
r4(n1)=i1(5*n1-3);
r5(n1)=i1(5*n1-4);

% converting each layer to binary
r1bt= dec2bin(r1);
r1btc=r1bt';
r1bs=r1btc(:);
r1b=str2num(r1bs);
 r1bb=r1b';

r2bt= dec2bin(r2);
r2btc=r2bt';
r2bs=r2btc(:);
r2b=str2num(r2bs);
r2bb=r2b';

 r3bt= dec2bin(r3);
r3btc=r3bt';
r3bs=r3btc(:);
r3b=str2num(r3bs);
r3bb=r3b';

 r4bt= dec2bin(r4);
r4btc=r4bt';
r4bs=r4btc(:);
r4b=str2num(r4bs);
r4bb=r4b';

r5bt= dec2bin(r5);
r5btc=r5bt';
r5bs=r5btc(:);
r5b=str2num(r5bs);
r5bb=r5b';
```

```
nb=1:16000;
% combing all the five layers in fives, one from each layer
%to form one large bit stream that is transmitted. 'irlayer'
irlayer(5*nb)= r1bb(nb);
irlayer(5*nb-1)=r2bb(nb);
irlayer(5*nb-2)=r3bb(nb);
irlayer(5*nb-3)=r4bb(nb);
irlayer(5*nb-4)=r5bb(nb);

var.time = (0:(80000-1))';
var.signals.values = irlayer';
```