

Simulation and Performance Analysis of Effect of AWGN/Fading Channel on Data Transmission Using OFDM

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Abstract

OFDM's capability to transmit data at high speed is making it be adopted as popular wireless and wired communication standards globally. In a wireless environment, signals may propagate through numerous paths before reaching the receiver (referred to as multipath propagation). This leads to phase shifting, destructive and constructive interference of the propagated signal. As a result, the received signal could have variable amplitude and phase due to changes in the propagation time and the intensity of distribution of the waves. This study investigated the effects of fading channels on OFDM, using simulation on MATLAB to mimic wireless fading channels environments that are based either on Doppler spread or on Delay Spread.

Keywords: OFDM, AWGN, Fading channel, Multipath propagation, Signal transmission and reception.

Introduction

Wireless transmission of data has undergone massive revolutions in the last few decades. The continuous need for a high and undisrupted data rates has always been the major concern telecommunications. Thus, different technologies have being developed over the years to meet up with the high data transfer rates needed to satisfy demanding applications such as video streaming, video conferencing, VoIP, etc. The most acceptable among this technology for wireless multimedia transmission which offers high data rate and immunity to a different issue that affects multipath propagation is orthogonal frequency division multiplexing (OFDM) (Banelli & Cacopardi, 2000).

OFDM is a modulation technology that adopts the concept of subcarrier modulation by making use of multiple subcarriers within the same single channel (Bae & Powers, 2013; Yang, Lim & Nirmalathas, 2013; Başar, Aygölü, Panayircı & Poor, 2013). It is a digital multi-carrier scheme that makes use of a large number of closely-spaced orthogonal subcarriers, which are transmitted in parallel rather than at a high stream rate of data with a single subcarrier. Subcarriers are orthogonal to one another, thus, a guard interval is added to each symbol to minimize the channel delay spread and inter-symbol interference while different digital modulation schemes, such as 16QAM, 32QAM, and QPSK, are modulated on each subcarrier at low symbol rate

(Agrawal & Raut, 2011). However, the combination of many subcarriers makes several instances of same data to be transmitted at once in parallel on separate channels) but at lower speed in each sub-stream in relation to the original signal. This enables data rates similar to conventional single-carrier modulation schemes within equivalent bandwidth. In 1960, the technology was conceived while researching into minimizing interference among channels that were close to each other in frequency. The research was carried out to achieve clean data transmission in situations prone to signal corruption and interference when more conventional modulation schemes were used (Tong, Ma, Zhang, Fong, Jia, Zhu, et al., 2013).

The idea of numerous closely spaced orthogonal subcarrier signals with overlapping spectra which are emitted to carry data with fast Fourier transform (FFT) algorithms as the demodulation was introduced. Weinstein and Ebert enhanced OFDM in 1971 by introducing a guard interval that provides better orthogonality in transmission channels affected by multipath propagation (Weinstein, 2009). Each signal (subcarrier) is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, which maintains total data rates similar to conventional single-carrier modulation schemes in the same bandwidth (Borra & Chaparala, 2013). Apart from its adoption for the 4G wireless communication and Internet access, OFDM is also used today in Wi-Fi, DSL and digital television and radio broadcast services. OFDM is the modulation technique for European standards such as digital audio broadcasting (DAB) and digital video broadcasting (DVB) (Coleri, Ergen, Puri, & Bahai, 2002).

It is said that the use of a Fourier transform algorithm makes OFDM better because it allows precise control of all those multiple frequencies (carriers) used to simultaneously carry many data bits in parallel on different frequencies. Discrete Fourier Transform (DFT) allows the control of multiple simultaneous carriers that are used to carry numerous data bit simultaneously. It relates the functions of the time domain to the frequency domain (Yu, Yen, Hsiung & Chen, 2011). However, multipath can cause errors and affect the quality of communications in digital radio communications like GSM (Molisch, 2012). This situation had been a serious challenge for multimedia data transmission. The effects being caused are on both wired and wireless transmission system, hence network designers are faced with a continuous challenge on how to evade the errors. The challenges have prompted researchers to investigate effective ways to minimize and mitigate multipath fading. However, in order to effect these changes, it is necessary to have an actual understanding of how these different conditions affect the transmission. Furthermore, a vivid effect of how multimedia data behave under different conditions of these transmission impairments must be understood. Thus, different models have been proposed and evaluated for understanding how different combinations of transmission channels and multimedia signals affect the transmitted signals (Khlifi & Bouallegue, 2011).

The study showed that one of the major obstacles facing the use of subcarrier technology is the effect of inter-symbol interference (ISI), which results mostly in the rapid fading of the channel (Agrawal & Raut, 2011). The type of fading experienced by the signal through a channel depends on the relation between the signal parameters (bandwidth, symbol period) and the channel parameters (delay and Doppler spread). However, different channels behave differently when each of these parameters is varied; so it is necessary to study these channels and determine the most suitable channel to be used for data transmission (Usha & Nataraj, 2013). It is known that OFDM with the aid of sufficient cyclic prefix (CP) can combat multipath fading in a slowly varying

channel. Nevertheless, in a rapidly fading channel, the system suffers from inter-carrier interference (ICI) that resulted from a rapidly time variation of the channel (Khare, Trivedi & Dixit, 2014).

The use of OFDM has increased greatly due to its numerous advantages such as high data rate transmission, the quality of the reception and its ability to combat ISI, especially in fading channels. However, considering the multipath effects, there is a need to investigate and adopt better solutions towards increasing network capacity and reducing transmission impairment i.e. eliminating multipath interference and determining the best channels to use.

Literature Review

Usha & Nataraj (2013) modulated each subcarrier using different modulation techniques. The authors then analysed the performance of OFDM paired with different modulation schemes for Additive-White Gaussian Noise (AWGN) channel. OQPSK modulation scheme, whose purpose is to limit the maximum phase change possible in QPSK was adopted in the study. Notwithstanding, the authors concluded that AWGN gives better performance compared to Rayleigh and Rician Fading channels.

Benarji, Rao & Setty (2015) compared the performance of OFDM system using QAM under the influence of AWGN, Rayleigh, and Rician fading channels. The OFDM signals were simulated with different faded signals by increasing the number of OFDM frames in AWGN, Rayleigh and Rician fading channels to understand the effect of channel fading and to obtain an optimum value of Bit Error Rate (BER) for a different number of antennas. The authors concluded that the modulation schemes should achieve low bit error rate in the presence of fading, Doppler spread, interference and thermal noise and also observed that the exact relation between the BER and the SNR is not easy to determine in the multi-channel environment.

The BER performance of the MIMO (Multi-Input Multi-Output) OFDM system for Rayleigh Fading Channel, as well as AWGN Channel along with a simulation channel using different modulation techniques was analysed by Agrawal & Raut (2011), while Banelli & Cacopardi (2000) obtained the analytical expressions for the BER performance by reviewing the analytical background for expressing the output correlation function for complex Gaussian signals that were being distorted by envelope dependent nonlinearities and used the results to propose a model for the analytical performance evaluation of OFDM systems in nonlinear AWGN channels. Computer simulations did validate the analytical derivations and the proposed model, and the authors disclosed that the existence of Guard Period plays an important role in improving the BER performance of the MIMO-OFDM system.

The effect of the carrier frequency offset on orthogonal frequency division multiplexing (OFDM) systems for multipath fading channels was analysed by Borra & Chaparala (2013). A simple approximate expression for the average signal-to-noise ratio (SNR) was derived, which was shown to be an upper bound of the average SNR for flat fading channels and an exact expression for the AWGN channel. They claimed that the frequency offset attenuated the desired signal and caused inter-carrier interference, thus reducing the SNR.

Bernardo, Zemen, Tufvesson, Molisch & Mecklenbräuker (2014) indicated that the "bad" subcarriers, which dominate the error performance of the OFDM system were least affected by the clipping noise. Thus, the degradation in the error performance of the OFDM system in fading channels was insignificant. They did not however consider the effect of channel fading on the

clipping noise; rather, the clipping noise was added at the transmitter and hence faded with the signal. In the study, the behaviour of propagation for all similar links under similar constraints for different mediums was analysed. Reasons were given for preferring AWGN as a simulated channel to a Rayleigh fading channel. Consequences of delay spread, Doppler Effect, IBI and ICI on transmitted data were analysed. How the system in a rapidly fading channel suffers from inter-carrier interference (ICI) which results from rapidly time variation of the channel compared to slow fading channel was shown. All these among others were done by investigating the behaviour of different transmission channels via analysis of the performance of OFDM over different mediums, using a simulation experiment where different channels were modelled to behave like different natural phenomena, which affect received signal over a wireless network.

The better BER performance of OFDM-BPSK 16-QAM and 64-QAM systems over AWGN fading channel was also reported by Shah, Rindhe & Narayankhedkar (2010). However, the performance of OFDM is compared in terms of BER versus SNR for different modulation formats. Panta & Armstrong (2004) investigated the different transport schemes for delivery of high-frequency broadband OFDM signals via fibre-wireless links, unlike we propose to do in this study where just wireless is being used. Panta & Armstrong (2004) claimed that the OFDM scheme offers high spectral efficiency and better resistance to fading environments. They also concluded that the QAM gives better performance under Rayleigh channel compared to other modulation schemes and channels. In the study was not used QPSK.

Nolan, Kazakevich, Tyra, Regis & Schreider (2006) proposed a communication transmission emulator where a variety of linear and non-linear distortion characteristics are impressed on a baseband signal between transmit and receive modems to effect systematic testing and optimization of modem performance without requiring transmission communication channel and/or frequency components. The issue of transmitter and receiver I/Q imbalances was addressed by Aziz, Ghannouchi & Helaoui (2017). Their simulation results showed that the proposed model resulted in a reduced error, reasonable image suppression, and a very low BER.

Methodology

The methodology adopted in this project is to develop a simulation model of a transmission medium communication channel, which makes use of OFDM multicarrier technology to transmit multimedia data over the communication channel. Data were transmitted over AWGN and Rayleigh fading channels by varying the different parameters known to affect transmission performances. A Matlab program to model different scenarios occurring when transmitting signals over a wireless channel was used. Different types of channels, modulation techniques and instances were created to transmit data over AWGN and fading channels using OFDM. The parameters were varied and the effects of each of the schemes were compared with theoretical results. Results from the simulation analysis were also compared to theoretical results. In the simulation, while analysing the behaviour of transmitted data, the movement of the packet over the wireless network was not documented. In the model used as a fading channel, the Line of Sight (LOS) was blocked. Thus, with some modifications to the structure, Rician distribution was generated to represent the presence of LOS between the transmitter and the receiver.

Simulation Results and Interpretation

1. Rayleigh channel with flat Doppler spread

The channel was created with the Rayleigh channel. Define the channel type:

Channel Type = Rayleigh

To create a flat Doppler spectrum object that is to be used for the Doppler Spectrum property of a channel object:

dop= doppler.flat

The normalized flat Doppler power spectrum was given analytically as:

$$S(f) = \frac{1}{2f_d} \text{ for } |f| \leq f_d, \text{ where } f_d \text{ is the maximum Doppler frequency}$$

Parameters of the channel: Set the sample time and maximum Doppler shift:

Sample Period = 1.0000e-06

Max Doppler Shift = 50

Properties: The flat Doppler spectrum object contains only one property, which is the Spectrum Type. It was observed that the default Doppler spectrum property was Jake's model. Therefore, the Doppler spectrum property was changed to flat:

Doppler Spectrum= [1x1 doppler.flat]

The channel was modelled to prove the presence of transmission medium, and since no data was transmitted, the number of samples processed was zero i.e. the channel recorded no signal transmitted.

Number Samples Processed: 0

2. QPSK modulation over AWGN channel

An AWGN channel object added white Gaussian noise to a real or complex input signal. When the input used a real-valued signal, this object added real Gaussian noise and produced a real output signal. When the input used a complex signal, this object added complex Gaussian noise and produced a complex output signal.

Adding white Gaussian noise to the signal

Defined and created additive white Gaussian noise channel object, which added white Gaussian noise to the signal:

H = comm.AWGNChannel

Then, set specified properties and specified value of AWGN noise input signal

H = comm.AWGNChannel(Name, Value)

Channel properties and parameters

Noise Method: Used to select the method to specify the noise level as one of signal to noise ratio (SNR). This could either be expressed in signal to noise ratio (Eb/No) or (Es/No):

Signal to noise ratio (Eb/No) = 20

Bit per symbol: Specify the number of bits in each input symbol.

Bit per symbol= 3

Modulation technique:

PSK modulation object=8

Method:

- Modulated the signal,
- Added white Gaussian noise to the modulated signal by passing the signal through an AWGN channel,
- Transmitted the signal through the AWGN channel,
- Plotted the noiseless and noisy data using scatter plots to observe the effects of noise,
- Changed the EbNo property to 10 dB to increase the noise,
- Passed the modulated data through the AWGN channel, and
- Plotted the channel output.

Figures 1 to 3 show the effects of AWGN in the transmission channel. The first plot (Figure 1) shows the channel noiseless since no AWGN was added. The second one with an SNR of 20 (Figure 2) shows a scatter plot of a noisy channel, while an increase in the SNR to 10 (Figure 3) shows a denser cluster in the plot indicating an increase in the noise level of the channel.

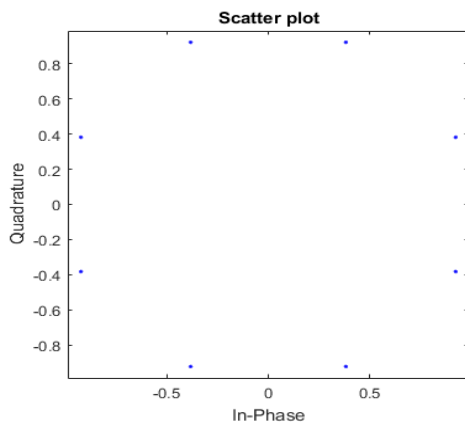


Fig. 1: Noiseless channel.

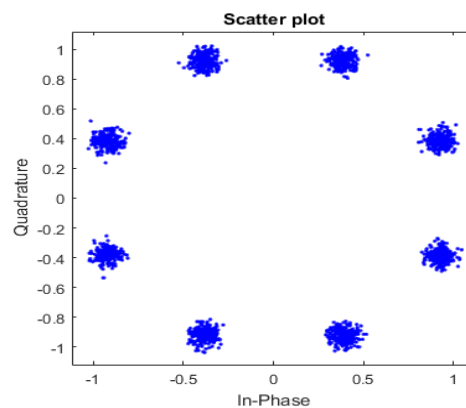


Fig. 3: Noisy channel (SNR=20).

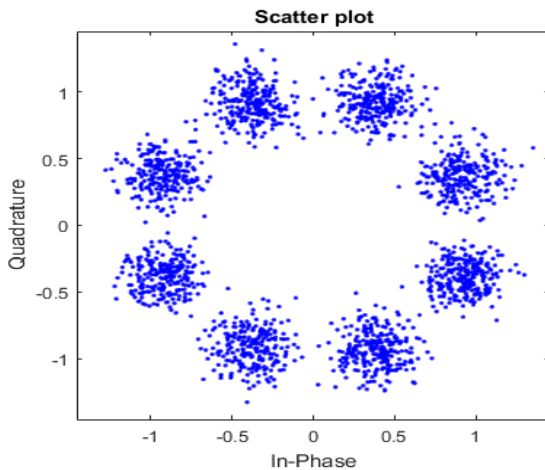


Fig. 3: Noisy channel (SNR=10).

3. *Creating and visualizing the frequency selective fading channel*

To visualize the effect of a frequency selective fading channel caused by different frequency components of signal experiencing different fading, three path delays were created and the three path gains were input. Then a Rayleigh channel was created and FSK (Frequency shift keying) and QPSK (Quadrature phase shift keying) signals passed through a Rayleigh multipath fading channel. Then, the signal bandwidths were changed to observe the impact of the fading channel on the FSK spectrum and the QPSK constellation. The channel was set to display the impulse and frequency response.

FSK:

- Set modulation order, modulated symbol rate, and the frequency separation.
- Calculated the samples per symbol parameter as a function of the frequency separation, modulation order and symbol rate to avoid output signal aliasing. Then, calculate the sample rate of the FSK symbol,
- Created an FSK modulator,
- Set path delays and average path gains for the fading channel,
- Created a Rayleigh channel using the defined parameters.
- Set visualization property to display the impulse and frequency responses.
- Generated random data symbols and applied FSK modulation.
- Plotted the spectrum of the FSK modulated signal.
- Passed the signal through the Rayleigh fading channel and applied AWGN
- Plotted the received signal spectrum.

QPSK:

- Set the symbol rate parameter,
- Generated random data symbols and applied QPSK modulation,

- Created a Rayleigh channel using the defined parameters.
- Set visualization property to display the impulse and frequency responses,
- Passed the signal through the Rayleigh channel and applied AWGN.
- Plotted the constellation.

Channel parameters: As detailed in Tables 1 and 2.

Table 1: FSK modulation parameters

Parameter	flat fading	Frequency selective fading
Symbol rate	45bps	45bps
Frequency separation	200khz	200khz
Signal bandwidth	800hz	800khz
Coherence bandwidth	50khz	50khz
Modulation order	4	4

Modulation order= 4; Path delays = [0 3 10]*1e-6; S/N ratio= 25.

Table 2: QPSK modulation parameter

Parameters	Flat fading	Frequency selective fading
Symbol rate	500bps	500kbps
Maximum Doppler shift	0.01	0.01

Data = ([0 3],10000,1);

PSK modulation= (data,4,pi/4,'gray'); S/N ratio=25

4. Effects of frequency selective fading channel on signal transmission

The results of the simulations are provided below.

FSK Modulation

(i) *Impulse response for flat fading and frequency selective fading channel:*

Figures 4 and 5 show the impulse response for flat fading and frequency selective fading channel.

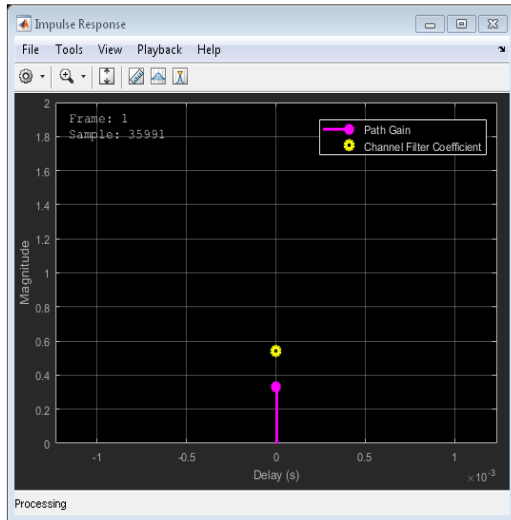


Fig. 4: Impulse response for flat fading Channel.

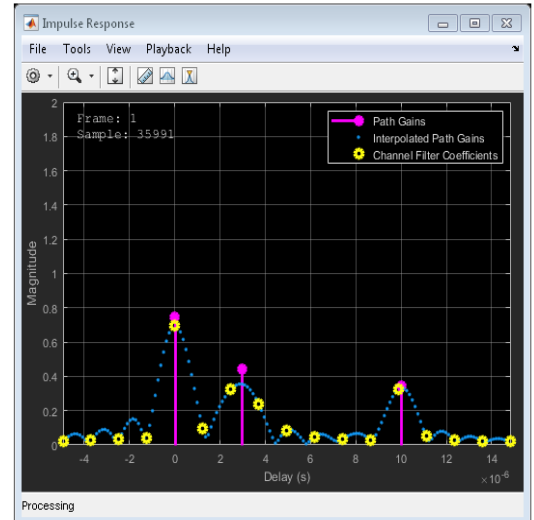


Fig. 5: Impulse response for frequency selective fading channel.

(ii) *Frequency response for flat and frequency selective fading channel*

Figure 6 and 7 show frequency response for flat and frequency selective fading channel

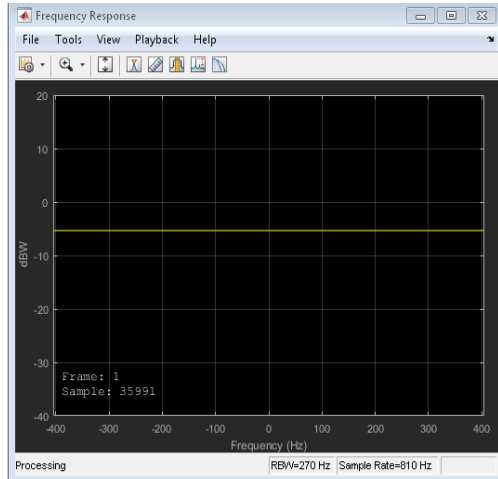


Fig. 6: Frequency response for flat fading channel.

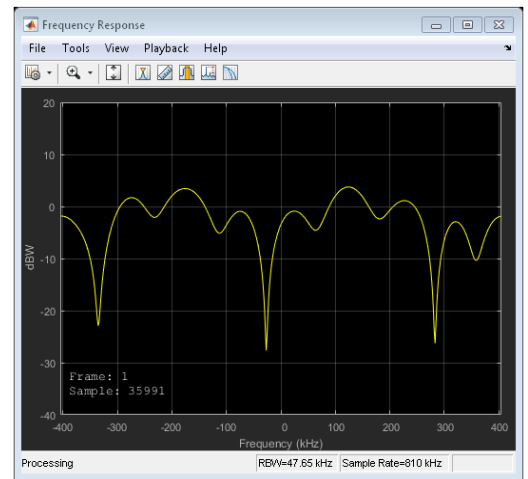


Fig. 7: Frequency response for frequency selective fading channel.

iii. *Received signal from spectrum analyser for flat fading and frequency selective fading channel*

Figures 8 and 9 show the received signal from spectrum analyser for flat fading and frequency selective fading channel.

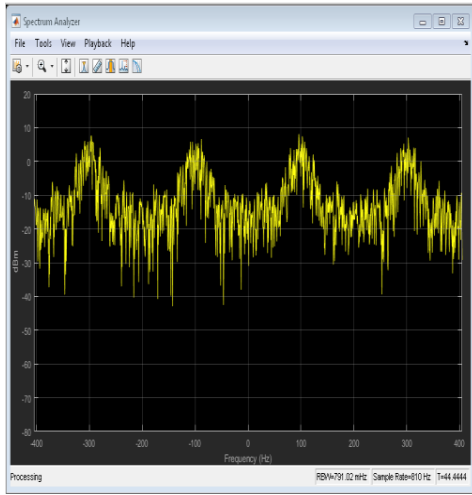


Fig. 8: Received signal from spectrum analyser for flat fading channel.

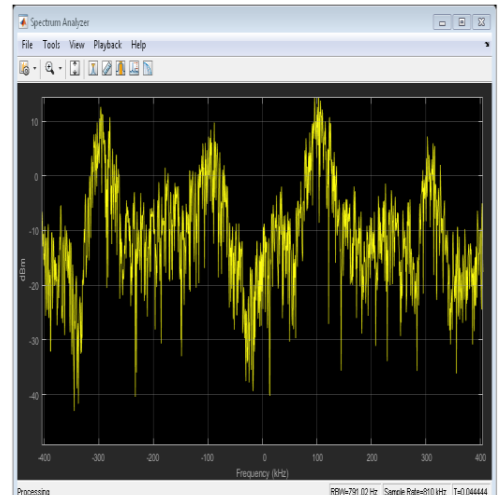


Fig. 9: Received signal from spectrum analyser for the frequency selective fading channel.

QPSK Modulation

i. QPSK impulse response for flat and frequency selective fading channel

Figures 10 and 11 show QPSK impulse response for flat and frequency selective fading channel.

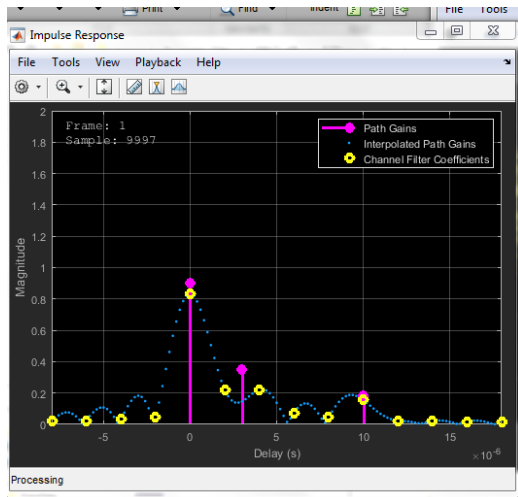


Fig. 10: QPSK impulse response for frequency selective fading channel.

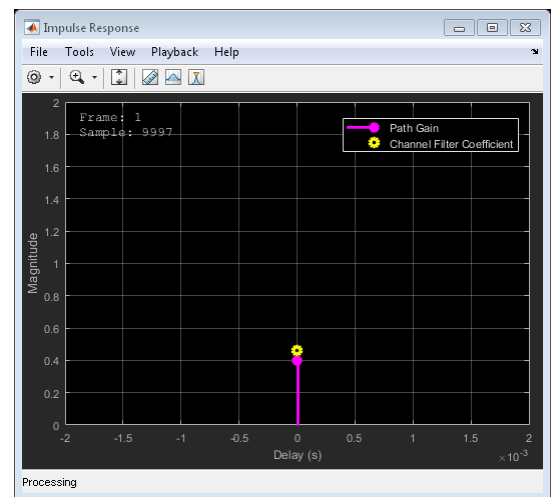


Fig. 11: QPSK impulse response for flat fading channel.

ii. QPSK frequency response for flat and frequency selective fading channel

Figures 12 and 13 show the Result of QPSK frequency response for flat and frequency selective fading channel.

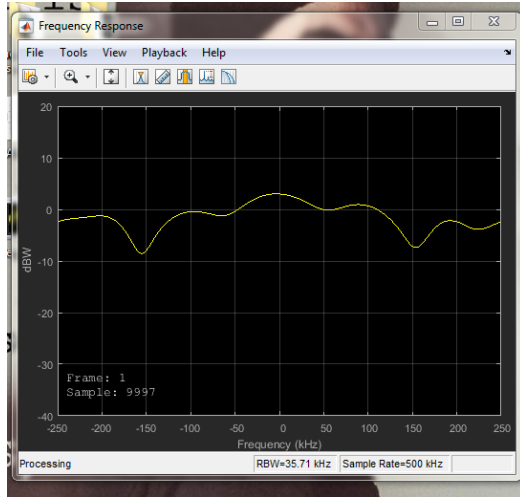


Fig. 12: Result of QPSK frequency response for frequency selective fading channel.

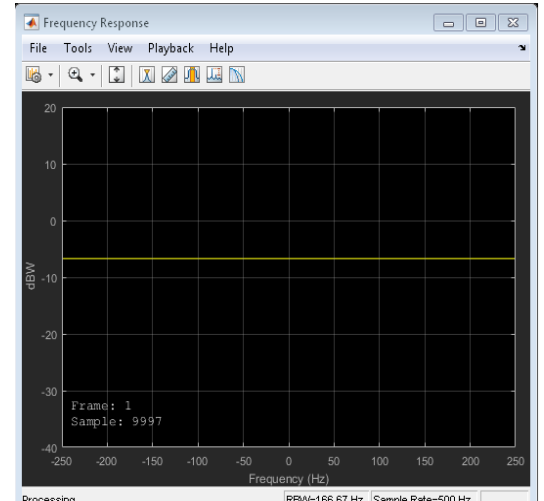


Fig. 13: Result of QPSK frequency response for flat fading channel.

iii. QPSK constellation for flat and frequency selective fading channel

Figures 14 and 15 show the QPSK constellation diagram for flat and frequency selective fading channel.

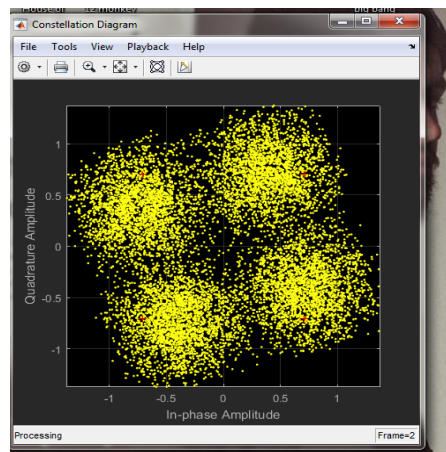


Fig. 14: The QPSK constellation diagram for frequency selective fading channel.

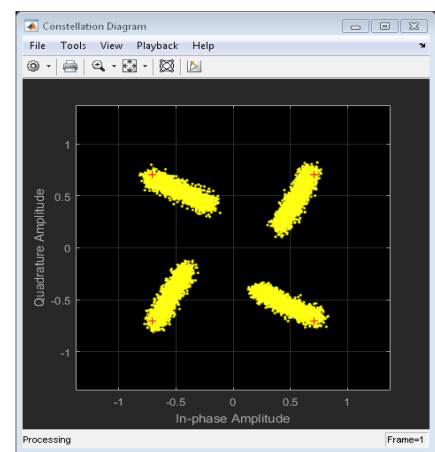


Fig. 15: The QPSK constellation diagram for flat fading channel.

The modulated signal was composed of four tones each having approximately 20 dBm peak power separated by 200 Hz. For the spectrum analysers flat fading, the four tones comprising the FSK signal maintained the same frequency separation and peak power levels relative to each other. Absolute peak power levels decreased due to the fading channel. The response of impulse

frequency for flat fading channels showed that the channel behaved as though it were flat. This was because 800 Hz signal bandwidth was much smaller than the coherence bandwidth.

For the frequency selective FSK channel, the spectrum has the same shape as in the flat-fading case but the four tones were now separated by 200 kHz. In FSK impulse and frequency responses for frequency selective fading, there were still four identifiable tones but their relative peak power levels differ due to the frequency-selective fading, also the signal bandwidth, 800 kHz, is larger than the coherence bandwidth, 50 kHz, showing that the multipath fading was frequency selective.

For QPSK impulse and frequency response for flat fading channel, the channel behaved as though it were flat. This was because the signal bandwidth, 500 Hz, was much smaller than the coherence bandwidth, 50 kHz. Alternatively, the delay span of the channel (10 microseconds) was much smaller than the QPSK symbol period (2 milliseconds) so the resultant band-limited impulse response was approximately flat. Besides, the QPSK constellation showed the effects of the fading channel; however, the signal still had four identifiable states.

However, for QPSK over frequency selective channel, the impulse and frequency responses showed that the multipath fading was frequency-selective because as the signal bandwidth was increased from 500 Hz to 500 kHz, the signal became highly distorted. This distortion was due to the ISI that came from the time dispersion of the wideband signal. The delay span of the channel (10 microseconds) was now larger than the QPSK symbol period (2 microseconds) so the resultant band-limited impulse response was no longer flat. Alternatively, the signal bandwidth was much larger than the coherence bandwidth of 50 kHz.

5. Comparison of Theoretical and Simulated Results of OFDM Signal Transmitted over AWGN modulated by QPSK

(a) Creating modulated and transmitted signal

- Constructed system objects for QPSK and OFDM modulators and demodulators. Then, the AWGN channel needed for the simulation,
- Set the QPSK modulator and demodulator to accept binary inputs,
- Set both OFDM modulator and demodulator in accordance with the simulation parameters
- Set the noise method property of the AWGN channel object to variance and defined the variance source property to enable the noise power to be set from an input port,
- Determined the input and output dimensions of the OFDM modulator,
- Determined the number of data subcarriers from the OFDM structure variable,
- Determined the OFDM frame size from the number of data subcarriers and the number of bits per symbol,
- Set the SNR vector according to the desired E_b/N_0 range, the number of bits per symbol, and the ratio of the number of data subcarriers to the total number of subcarriers,
- Initialized the BER and error statistics arrays,
- Simulated the communication link over the range of E_b/N_0 values
- Determined the theoretical BER for a QPSK system,
- Plotted the theoretical and simulated data on the same graph to compare results.

(b) *Parameters:*

Modulation alphabet=4; Bits/symbol=log₂(M); Number of OFDM subcarriers=128
OFDM cyclic prefix length=32; Maximum number of bit errors=100
Maximum number of bits transmitted=1e7; Data input size: [117 1]; Output size: [160 1]
The result is as seen in Figure 16.

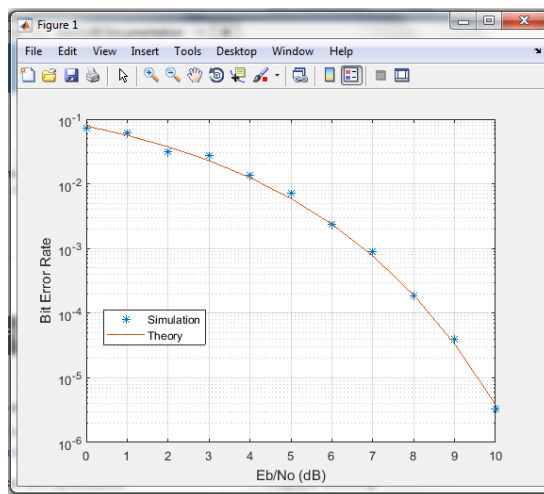


Fig. 16: Graph of theoretical and simulated QPSK modulated signal over AWGN.

From the graph (Figure 16) theoretical and simulated QPSK modulated signal over AWGN, it was observed that the simulated and theoretical data were in accordance.

6. *Simulation of an QPSK Transceiver*

Simulating a QPSK transmitter and receiver in real-world wireless communication issues such as carrier frequency, phase offset, timing recovery, and frame synchronization, the transmitted QPSK data experienced impairments, which had effects on wireless transmissions, such as the addition of AWGN, the introduction of carrier frequency and phase offset, and timing delay. To deal with these impairments, the receiver included FFT-based coarse frequency compensation, PLL-based fine frequency compensation, PLL-based symbol timing recovery, frame synchronization, and phase ambiguity resolution.

Creating the model

The entire architecture for the model was in three main components.

- i. A QPSK transmitter generating the bitstream and encoding, then using a QPSK modulation to modulate the data before filtering it using a square root raised cosine filter.
- ii. A QPSK channel modelled to simulate the effects of over-the-air transmission. The channel degraded the signal with carrier offset, timing offset, and AWGN to enable impairments occurring on the transmitted signal as it moved from the transmitter to the receiver.

- iii. Finally, a QPSK receiver used to models the component that received and regenerated the originally transmitted message making use of components such as automatic gain control, coarse frequency compensation, fine frequency compensation, timing recovery, preamble detection, frame synchronization, and data decoding.

The resulting signal was then viewed using time scopes, frequency scopes, and constellation diagrams.

Parameters:

Modulation alphabet=4; Up sampling= 4; Down sampling=2; Fs= 200000; Ts= 5.0000e-06
Frame size= 100; Barker length=13; Data length= 174; Scrambler base= 2; Scrambler polynomial=[1 1 1 0 1]; Scrambler initial conditions= [0 0 0 0]; S bit= [17400×1 double]
Rx buffered frames= 10; Raised cosine filter span=10; Message length=105
Frame count= 100; Phase offset= 47; Signal to noise ratio= 13; Frequency offset= 5000
Delay type='Triangle'; Coarse Comp frequency resolution= 25; Phase recovery loop bandwidth= 0.0100; Phase recovery damping factor= 1;
Timing recovery loop bandwidth= 0.0100; Timing recovery damping factor= 1
Timing error detector gain= 5.4000; Modulated header= [13×1 double]
Roll off= 0.5000; Transmitter filter coefficients= [1×41 double]
Receiver filter coefficients= [1×41 double]

The results are show in Figures 17 to 20. Constellation diagram after fine frequency compensation (Figure 17), spectrum analyser after raised cosine Rx filter (Figure 18) and the graph of time scope for normalized timing error (Figure 19) showed that the different components used for phase recovery, timing recovery, decoding, demodulation, and so on had helped in recovering the correct signal from the signal that was corrupted by various simulated channel impairments (carrier offset, timing offset, and AWGN) that were earlier introduced into the channel.

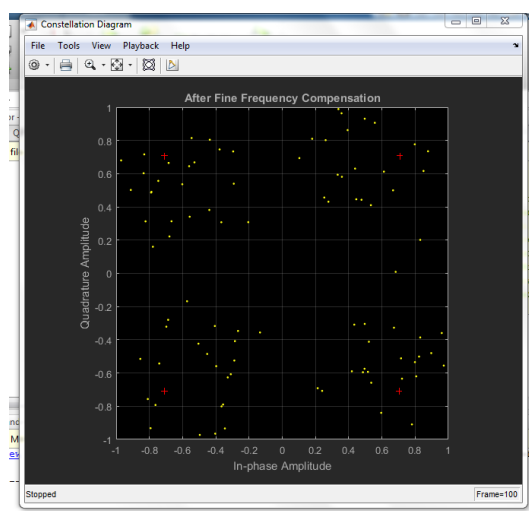


Fig. 17: Constellation diagram after fine frequency compensation.

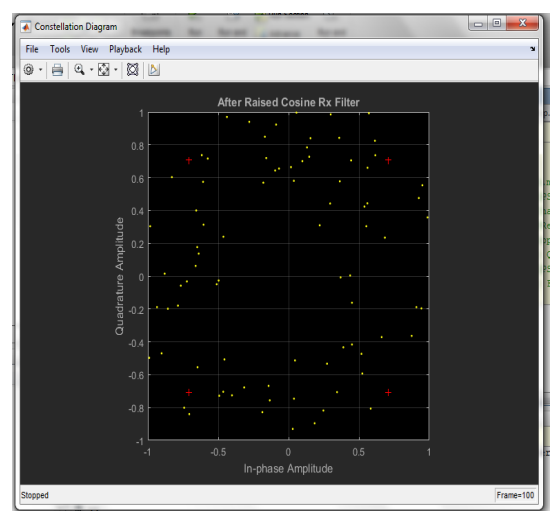


Fig. 18: Constellation diagram after raised cosine Rx filter.

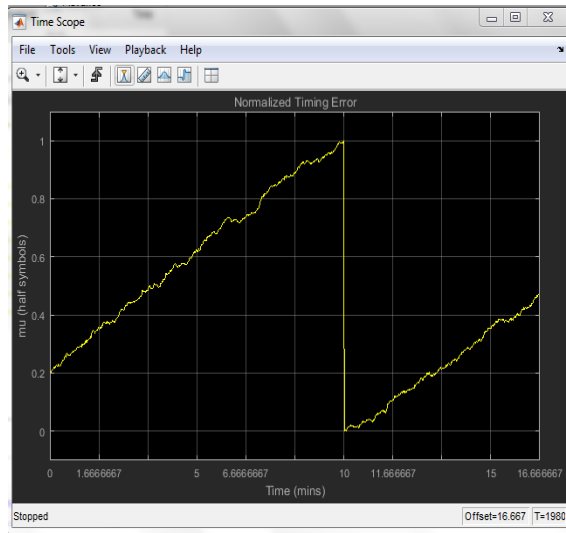


Fig. 19: Time scope for normalized timing error.

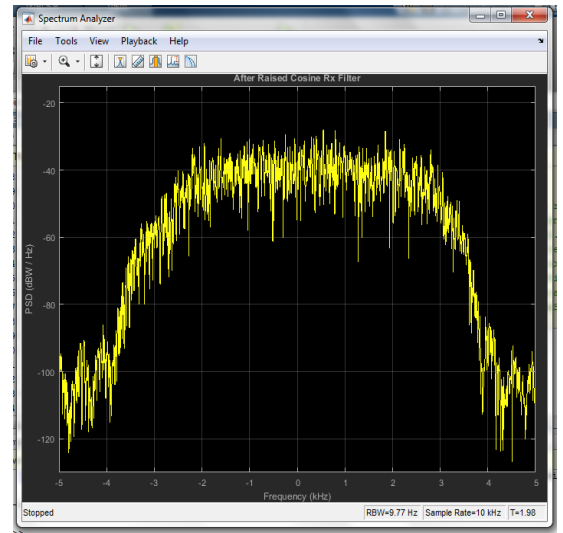


Fig. 20: Spectrum analyser after raised cosine Rx filter.

From the signal transmitted, the following bit error data rate was recovered from the transmission:

Error rate = 0.002501;
Number of detected errors = 26;
Total number of compared samples = 10395.

7. Comparing Empirical To Theoretical Result In Fading Channel

(a) Creating the model:

- Created a Rayleigh fading channel object;
- Generated data and apply fading channel;
- The computed error rate for different values of SNR;
- Created an AWGN channel and error rate calculator System object;
- Created an AWGN channel and error rate calculator System object;
- Add Gaussian noise;
- Demodulated
- Computed error rate.
- Computed theoretical performance results, for comparison.
- Plotted BER results

(b) Parameters:

Channel type = Rayleigh channel(1/10000,100); tx = randi([0 M-1],50000,1)
SNR = 0:2:20; Modulated alphabet=2

The result is as shown in Figure 21. With the parameters, the fading was slow enough to be considered the same across two consecutive samples. The resulting plot of theoretical and simulated results for the BER fading channel (Figure 21) shows that the simulation results were close to the theoretical results computed by BER fading.

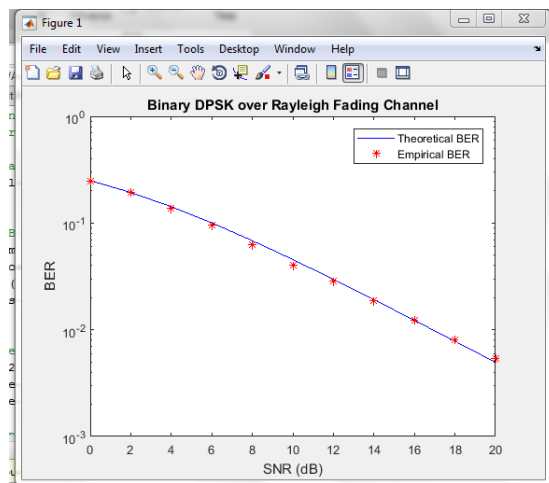


Fig. 21: Graph of theoretical and simulated result for BER fading channel.

Discussion

Coleri, Ergen, Puri, & Bahai (2002) had concluded that the modulation schemes should achieve low bit error rate in the presence of fading, Doppler spread, interference and thermal noise, and also observed that the relation between the SNR and the BER is not easy to determine precisely in the multi-channel environment. Similarly, Borra & Chaparala (2013) concluded that the performance of the OFDM system is better if QAM or QPSK is selected as the modulation technique instead of BPSK and that OFDM performs better under Rayleigh Fading channel compared to Rician and AWGN Channel as it yields low BER for each SNR value. It was deduced by Usha & Nataraj (2013) that AWGN gives better performance when compared to Rayleigh and Rician Fading channels. Most of these claims were observed and upheld in this study, as visualized in Figures 2 to 21. However, it is obvious that these studies were focused on finding a channel to prefer over others for transmission, and not how to minimize or eradicate the effect of fading. Notwithstanding, a blind frequency-independent I/Q imbalance compensation method that was based on the maximum likelihood estimation of the imbalance parameters of a transceiver for the mitigation of in-phase and quadrature-phase imbalance at the transmitter (pre-compensation) was proposed by Aziz, Ghannouchi & Helaoui (2017). Though the approach is different from the one adopted in this study, it was aimed at mitigating impairment issue of transmitter and receiver. Nolan, Kazakevich, Tyra, Regis & Schreider (2006) had proposed a communication transmission emulator that digitally emulates a plurality of signal impairments. However, they did not proffer

any solution on recovering the signal that is corrupted by the impairments, as has been done in this study.

Conclusion

This study investigated how various transmission impairments affect different channels and provided a better understanding of how different communication signals responds to channel fluctuations. It also provided an in-depth understanding of how subcarrier technology affects a high data rate, which is the benefit of OFDM technology. Furthermore, from the results of studies on the effect of AWGN on a different type of fading channels (Rayleigh fading channel, frequency selective fading channel and flat fading) with the effect of Doppler spread on data transmission in a wireless transceiver model, it was deduced that the various channel impairments like carrier offset, timing offset, and AWGN could not be eradicated in a channel but their effects could be minimized using components such as automatic gain control, coarse frequency compensation, fine frequency compensation, and timing recovery which, from the results of this study, helped in recovering the signal that was corrupted by the various simulated channel impairments. These findings provide a base for future technology design as, with the parameters, the fading was slow enough to be considered the same across consecutive samples.

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