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Performance Evaluation of Digital Modulation Techniques in Multi path Communication Channel Interface Air

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Abstract--This paper investigates the performance of different digital modulation techniques in Multipath fading channel interface air. The paper describes characteristics of wireless communication channels with emphasis on fading channel. This study examines the inherent attributes of the digital modulation schemes to overcome the impairment introduced by the channel. The channel was modeled and simulated using 6 rays. The evaluation of the different modulation techniques was carried on the modeled multipath channel. This was carried out to understand the contributions of channel characteristics to effective wireless communication. The BER for simulated modeled channels agreed with the theoretical results. It was also observed that multipath fading channel characteristic limits the data rate in wireless communication.

***Index Terms*—BER, communication channels, modulation and Noise**

I. INTRODUCTION

The performance of wireless communication system depends largely on the characteristics of the wireless channel which is rather unpredictable and dynamic, therefore making the design and analysis of wireless communication systems very tasking and mostly difficult [1,]. A good understanding of the channel impulse response (CIR) will provide a good platform for the development of high performance and a bandwidth efficient wireless transmission technology. This work is investigating the channel impairment to wireless communication as it affects increasing the data rate, especially the fading characteristics of the channel. Because of the growing trend in Mobile communication, the work focuses on this area. The effect of increasing the bandwidth to 20MHz is investigated.

II. WIRELESS CHANNEL MODEL AND CHARACTERISTICS

In the design of communication systems for transmitting information through physical channels, we find it convenient to construct mathematical models that reflect the most important characteristics of the transmission medium. Wireless channel is an unguided channel and signals not only contain the direct Line of Sight LOS waves; but also a number of signals as a result of diffraction, reflection and scattering. This propagation type is termed Multipath [2] degrades the performance of the channel.

A. Additive White Gaussian Noise Channel

Additive White Gaussian Noise (AWGN) channel is a good model for the physical reality of channel, as long as the thermal noise at the receiver is the only source of disturbance [3]. Additive noise arises from electronic components and amplifiers at the receivers. Channel attenuation is easily incorporated into the model. The received signal affected by attenuation is usually expressed mathematically as shown in (1)

$$r(t) = \alpha s(t) + n(t) \qquad (1)$$

whereα is the attenuation factor, r(t) is the received signal, s(t) is the transmitted signal and n(t) is the noise.

B. Multi Path Fading Channels

Multipath fading channel is usually modeled as Rayleigh and Rician fading channels. The channel characteristics are usually modeled as shown in (2) [4].

$$h = a e^{j\emptyset} \qquad (2)$$

Where$a$ is the Rayleigh distributed magnitude and $\emptyset$ is the phase uniformly distributed in the interval $[-\pi, \pi]$.

The received power Pr in a wireless communication channel, with P being the transmit power and h is the channel characteristics, is given by (3)[4]

$$Pr = P \times |h|^2 \qquad (3)$$

Received signal to noise ratio (SNR) is Pa^2/σ_n^2, where $\sigma_n^2$is the noise power.

The BER is an average quantity and not an instantaneous quantity as expressed by (4).

$$BER = \int_0^\infty Q\left(\sqrt{\frac{a^2 P}{\sigma_n^2}}\right) 2a\, e^{-a^2/2} da \qquad (4)$$

Making a substitution $u = \frac{x}{a\sqrt{\mu}}$, flipping the order of integration and simplifying the resulting expression, then BER becomes:

$$BER = \sqrt{\mu}\int_1^\infty \int_0^\infty \frac{2a^2}{\sqrt{2\pi}}\, e^{-\frac{a^2}{2}(2+\mu u^2)}\, dadu \qquad (5)$$

Finally, the BER is related to the SNR by the expression in (6).

$$BER = \frac{1}{2}\left(1 \sqrt{\frac{SNR}{2+SNR}}\right) \qquad (6)$$

At high SNR, the expression above reduces to

$$BER \cong \frac{1}{2 \times SNR} \qquad (7)$$

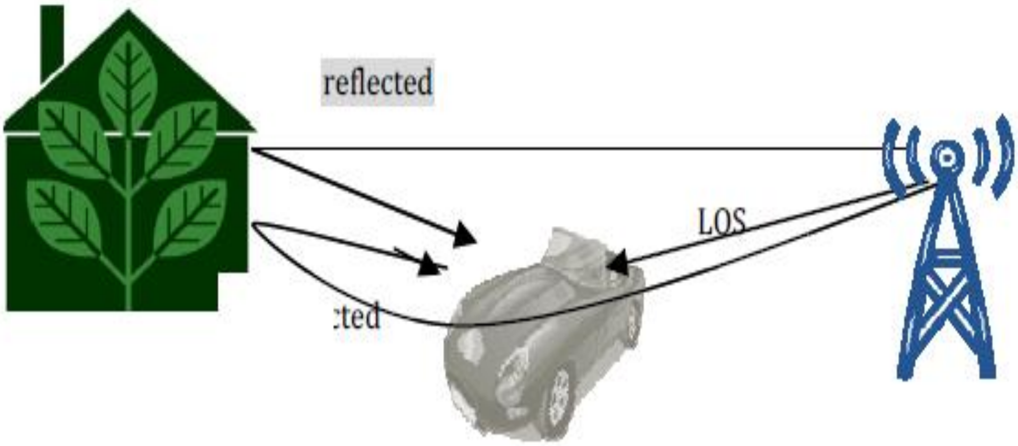

Fig 1: Multipath Signal Reception

An alternative class of channel used to model communication system is fading channels because mobile reception is harshly affected by multipath propagation which results in Fading or Inter-symbol Interference (ISI). This can be mathematically expressed as:

$$r(t) = s(t) * h(t) + n(t) \qquad (8)$$

Where $s(t)$the transmitted symbol is$h(t)$is the channel characteristics and $n(t)$is the noise on the channel, modeled as additive white Gaussian noise (AWGN).

C. *Flat and Frequency Selective Fading Channel*

In the slow fading scenario, the channel remains constant over the transmission duration of the codeword. If the codeword length spans several coherence periods, then time diversity is achieved and the outage probability improves. When the codeword length spans many coherence periods, we are in the so-called fast fading regime. Time disperse signal are often affected by the delay spread. If the delay spread is less than the symbol period *Ts*, the signal channel is categorized as *Flat fading* which preserves the spectral characteristics of the signal at the receiver [2]. In contrast, if signal bandwidth is more than the coherence bandwidth or delay spread is more than the symbol period, then the channel is categorized as *Frequency Selective fading* and leads to ISI which degrades the channel

III. CHANNEL MODELS

Andrea stated in [4] that deterministic channel models are rarely available. But to evaluate the performance of signals properly in fading channels, this work considered Flat and Frequency Selective fading channel and few of the models.

A. *Rayleigh and Rician Fading Model*

A wireless radio channel whose delay spread is less than symbol period and the signal bandwidth is less than the coherence bandwidth where the channels are correlated, can appropriately be modelled as Rayleigh fading which assumes that a received multipath signal contains infinite or large number of arrival paths at the same time whose gain are statistically independent and no dominant path**.** Rayleigh distribution model is often used for fading signal with infinite or large number of arrival paths at the same time whose gain are statistically independent and no dominant path[4]. The phase component of the channel gain is Gaussian distributed and (9) is its probability density function (PDF) as stated by Rappaport [5]:

$$p(r) = \begin{pmatrix} \frac{r}{\sigma^2} e^{\left(-\frac{r^2}{2\sigma^2}\right)} & 0 \leq r \leq \infty \\ 0 & r < 0 \end{pmatrix} \qquad (9)$$

Where, σ is the RMS value of received signal before detection. And according to [2], the average channel power is given by:

$$E[r] = 2\sigma^2 \qquad (10)$$

The received signal power is often weak in a fading channel and bit error occurs [3]. The theoretical average Bit Error Rate of Rayleigh fading channel model is given by [2] as stated in (11) :

$$AvBER = \frac{1}{2}\left(1 - \sqrt{\frac{E_b/N_0}{1 + E_b/N_0}}\right) \qquad (11)$$

Where E_b is the bit energy and N_0 is the noise power. Similar to the distribution properties of Rayleigh is the *Rician Distribution* model except for the presence of a dominant path with numerous weak paths. Inclusive in its pdf (equation 6 [2]) is the peak amplitude *A* of dominant signal and zero-order Bessel function I, of the first kind

$$p(r) = \begin{pmatrix} \frac{r}{\sigma^2} e^{\left(-\frac{r^2+A^2}{2\sigma^2}\right)} I_0\left(\frac{Ar}{\sigma^2}\right) & A \geq 0, r \geq 0 \\ 0 & r < 0 \end{pmatrix} \qquad (12)$$

B. *Jake'sFading Model*

The ray-based model is given by a sum of the arriving plane waves; it usually models the plane waves arriving from different arbitrary directions. A Rayleigh fading channel subject to a given Doppler spectrum can be generated by synthesizing the complex sinusoids. The number of sinusoids to add must be large enough to approximate the Rayleigh amplitude. Furthermore, each of the sinusoidal generators must be weighted to generate the desired Doppler spectrum. The Jake's model assumes that all rays of the scattered components arriving in the uniform directions are approximated by Nplanewaves [4].

C. ITU Model

A power delay profile (PDP) for the multi-path channel is required for modeling a frequency-selective fading channel. The PDP provides a distribution of the average power for the received signal over individual path, which is represented by the relative power of each path with respect to the power of the earliest path [4]. International Telecommunications Union published some generic test models that are commonly used in the communication industry. Depicted in [2] are the three common cases of the model- Indoor, Pedestrian and Vehicular. Table 1 shows the PDP parameters of the models. But in this work, the interest is in the Channel B type of the Pedestrian model with 6 rays, median delay spread (750 *ns*) and 55% probability of occurrence in an outdoor to indoor environment. Each tap is modeled using Rayleigh fading distribution characterized by Jakes' model to incorporate a model of the Doppler spectrum. From table 1, the rays are Rayleigh distributed with Classic Doppler spectrum defined [7] as:

$$S(f) \propto \frac{1}{\sqrt{1-\left(\frac{f}{f_d}\right)^2}} \qquad for\ f \epsilon - f_d . f_d \quad (13)$$

Assuming all the paths arrives at the same time and are uniformly distributed, the PSD is modelled as [4]:

$$\tilde{a}(t) = \sum_{i=0}^{N-1} a_i\, e^{j(2\pi f_i t + \theta_i)}, f_i = f_d \cos\theta_i \qquad (14)$$

$$S_h(f) = \mathcal{F}\{R_h(\Delta t;\tau)\} \qquad = \begin{cases} \dfrac{P_{av}}{\sqrt{1-\left(\frac{f}{f_d}\right)^2}} & |f| < f_d \\ 0 & |f| > f_d \end{cases} \qquad (15)$$

Where R_h is channel autocorrelation function, P_{av} is the average channel power, F_i is the Doppler shift in direction of travel for path θ_i and ã is the channel response in relation to Doppler shift. Table 1 is shown in Appendix.

IV. BAND PASS MODULATION

The mapping between the digital sequence and the signal sequence to be transmitted over the channel can either be memoryless or with memory, which therefore gives rise to memoryless modulation schemes and modulation schemes with memory. Memoryless modulation schemes include Pulse Amplitude Modulation (PAM), Quadrature Amplitude Modulation (QAM), and Phase Modulation such as PSK, QPSK, and BPSK. Modulation schemes with memory can best be explained in terms of Markov chains and finite state machine, and the Continuous-Phase Frequency Shift Keying (CPFSK), Continuous-Phase Modulation (CPM), Minimum-Shift Keying (MSK), Offset QPSK (OQPSK) are some of the general types of the scheme. The power spectral density of linearly modulated signals, such as PSK, ASK and QAM usually have the low pass equivalent of the form

$$v_l(t) = \sum_{n=-\infty}^{\infty} I_n g(t-nT) \qquad (16)$$

Where I_n the stationary information is sequence and $g(t)$ is the basic modulation pulse.

The band pass equivalent signals is denoted by $v(t)$ with a low pass equivalent signal of the form in (17)

$$v(t) = \sum_{n=-\infty}^{\infty} s_l(t-nT;\, I_n) \qquad (17)$$

Comparing (8) and (9), then

$$s_l(t, I_n) = I_n g(t) \qquad (18)$$

With $R_l(k)$ being the autocorrelation function of the information sequence I_n, and $G(f)$ being the Fourier transform of $g(t)$, then

$$S_{vl}(f) = \frac{1}{T}|G(f)|^2 \sum_{k=-\infty}^{\infty} R_l(k) e^{-j2\pi kfT} \qquad (19)$$

$$S_{vl}(f) = \frac{1}{T}|G(f)|^2 S_l(f) \qquad (20)$$

From the above deductions represent the power spectral density (PSD) of the discrete-time random process I_n, it is therefore to be noted from above that the PSD depends on two factors, which are the shape of the pulse used for modulation and the correlation properties of the information sequence [8]. The shape of the pulse used for modulation accounts for the varying performance of different modulation schemes. Modulation is a process of transforming signal into waveforms that are compatible with the channel properties [8] and this is necessary in wireless communication where the antenna diameter must be at least equal to the wavelength of the carrier [9]. To transmit such data over the channel, a signal that represents the data and matches the channel property is generated. Since, there is a limitation in antenna size that can meet efficient signal transmission, data signal are super imposed on carrier-wave by shifting the information bearing signal to the frequency band of the channel [11]. Base band signals can be translated to higher frequency range. This technique is known as *band pass modulation* which is used in wireless and mobile communication, supporting small size antenna design for mobile equipments. Three main parameters-amplitude, phase, frequency can be exploited to produce a modulated signal[9], which leads to three generic modulation scheme namely Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK).

For a given digital data of finite bit sequence to be transmitted over a channel by a band pass filtered signal s(t), a mapping process known as digital modulation is required between the bit sequence and possible signals [2,10]. The mapping rule is also needed for proper demodulation and detection at the receiver. Also, signals can consider information bits in groups known as *symbols* and generate one wave form for each group. That is, transmitted data can have *M* numbers of symbols in a signal constellation or word length and *k* numbers of bit within each symbol. The k numbers of bits contained per symbol is guided by

$$k = \log_2(M) \qquad (21)$$

and M ε [2,4,8……M].

The general form of modulated signal s(t) is

$$s(t) = A(t)\cos[w(t)t + \emptyset(t)] \qquad (22)$$

Where A is the amplitude, w is the frequency and $\emptyset$ is the phase of the signal

A. *Phase Shift Keying*

This is the modulation mode of where the phase Ø(t) parameter of the signal is varied. The transmitted information is contained in *M* possible phase values. The values are also represented on the constellation maps. Hence for every phase value, *k* numbers of bit is represented. Increase in symbol rate gives a corresponding increase in bit rate and offers an advantage that while the symbol period remains constant, the bandwidth remains unchanged. The BER equation of M-PSK modulated signal in an AWGN channel [9] can be expressed as:

$$P_b = \left(\frac{1}{k}\right) erfc\left(\sqrt{\frac{kE_b}{N_0}}\sin\left(\frac{\pi}{M}\right)\right) \qquad (23)$$

Where $E_b$is the signal energy, N_0 is the noise power, M is the number of phase carrying data and k is the number of bit per symbol

B. *Quadrature Amplitude Modulation*

QAM is a hybrid modulation technique that takes its implementation from combining variations of both the amplitude A(t) and phase Ø(t) of the signal. The structure is similar to that of PSK, but the amplitude takes on a different range of value pairs [9]. Which means it uses the amplitude of the quadrature carrier signal to carry the data. QAM produce a better distribution of signal states in the signal constellation and variety of shape can be achieved. Data is stored in *M* possible symbols that can be located at any amplitude and phase dimension. It can also achieve increase in bit rate without bandwidth expansion. However, due to its superior bit packing structure, it has a lower probability of error performance than PSK when *M* possible values are more than 8. Alsusa in [14] stated the bit error probability as shown in (24):

$$P_b = \left(\frac{1}{k}\right) erfc\left(\sqrt{\frac{3k\,E_b}{2(M-1)N_0}}\right) \qquad (24)$$

QAM utilizes various phase shifts to the carrier, with each of these phase shifts having the ability to possess two or more discrete amplitudes. In this way, every amplitude/phase combination can symbolize a different and distinct binary value. As an example, if working with QAM-8, a digital value of 111 could be represented by a carrier that displays a phase shift of 180° and an amplitude of +2; or 010 can be symbolized if the phase is shifted to 90° with a amplitude of −1. QAM-8 exploits four phase shifts and two carrier amplitudes for a total of eight possible states, or 3 bits of 000, 001, 010, 011, 100, 101, 110, and 111 that can be transmitted.

C. *Error Probability*

A key performance metric of digital information transmission over a channel in communication system is the measure of errors in the transmitted bits or symbols. This is the amount of information error that is experienced when transmitting over a channel at certain Signal energy to Noise power Ratio (SNR), depending on the modulation scheme. It follows a simple statistical grading of the numbers of error and often referred to as Bit Error Rate (BER) or Symbol Error Rate (SER) [9].

V. IMPLEMENTATION

The implementation was carried out on a modeled channel as follows a Rayleigh fading channel, with the strong assumption that white noise is an inherent part of any modelled channel.4 and 6 rays flat fading channels was simulated in MATLAB for different Band pass modulation techniques. The multipath model employed for this work is the Jake's model. BPSK, QPSK, 16-QAM, and 64-QAM modulation techniques have been used for the simulation and the BER analysis have been shown for SNR being varied from 2dB to 22dB.

VI. RESULT PRESENTATION AND DISCUSSION

Based on the established Equations for different modulation scheme, the theoretic formulation was developed. To understand better the importance of BER measurement in different modulation, simulated BER results of some modulation scheme is provided in Fig. 2 to Fig.6.

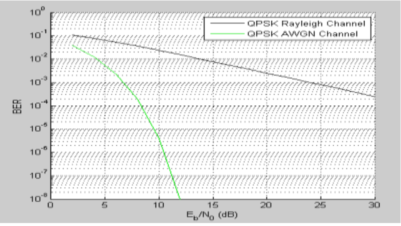

Fig 2: BER Comparison of QPSK in Rayleigh Fading and AWGN Channels

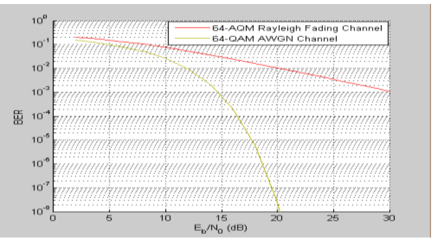

Fig.3: BER Comparison of 64-QAM in AWGN and Rayleigh Fading Channels

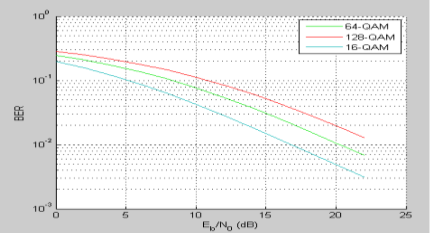

Fig.4: BER Performance of 16-, 64-, and 128-QAM in Rayleigh Fading Channel

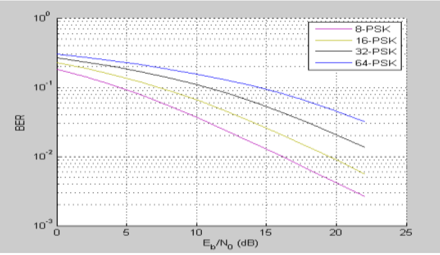

Fig. 5: BER Performance of 8-, 16-, 32- and 64-PSK in Rayleigh Fading Channel

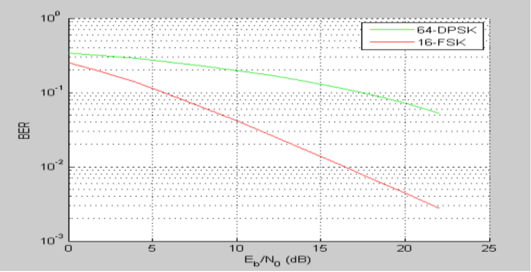

Fig. 6: Comparing BER Performance of PSK and FSK Rayleigh Fading Channel

It can be shown from the figures above that flat fading model channel of Rayleigh Fading statistics has a steady slope in its BER curve. With every increase in the Signal power, the Bit error in received signal reduces steadily. The comparison of the theoretical and simulated Bit error rate of QPSK signal in a Rayleigh fading channel (Fig 8) over an increasing signal power shows that the result are closely related especially at a low signal power but the simulated result tends to deviate as the signal power increases. The deviation can be assumed as a result of the randomness of large numbers of iterated value employed in the program, since the model is taking into account infinite arrival paths. Figure 9 compares the performance of the modulation in different channels. The BER Performance for various modulation techniques are presented to show the interactions between the fading channels and the techniques. The Bit Error Rate BER only improves slowly with a steady slope when plotted on a log normal scale which is contrast to a non-fading channel whose BER improves rapidly as shown in Fig 13. The result is supported by [3]. From Fig. 2, it was observed that the BER performance of AWGN channel improves rapidly and offers a better performance than Rayleigh fading channel. This is because Rayleigh fading channel is characterized by multipath signal and it is computed by average BER. The average BER is dominated by poor BER of individual path and variations in instantaneous BER. Hence, it offers a poorer BER performance. The results also show that the performance of 64QAM is better compared to the other modulation scheme.

VIII. CONCLUSION

The performance of Band pass modulation in Multipath channel was investigated. The simulated results of BER agree with the theoretical values obtained for the modulation schemes. It was observed that BER performance of band pass modulation in Rayleigh fading channel reveals the effects of Multipath on the signal. This shows that the integrity of the data is compromised as the data rate increases. The 64QAM shows a better performance compared to other digital modulation techniques. The result clearly shows that multipath effect limits the capacity of such channel.

REFERENCES

[1] N. Miki, Y. Kishiyama, K. Higuchi, and M. Sawahashi, "Optimum Adaptive Modulation and Channel Coding Scheme For Frequency Domain Channel-Dependent Scheduling in OFDM Based Evolved UTRA," IEEE WCNC, 2007.

[2] D. So, "Mobile and Wireless Communication," in Communications Engineering Lecture Notes: University of Manchester, 2010.

[3] H. Schulze and C. Luders, Theory and Application of OFDM and CDMA: John Wiley, 2005.

[4] Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley & Sons (Asia) Pte Ltd, 2, Singapore, 2010

[5] T. S. Rapp port, Wireless Communications: Principle and Practice, 2nd ed.: Prentice Hall 2002.

[6] D. D. Bevan, V. T. Ermolayev, P. M. Grant, A. G. Flaksman, and I. M. Averin, "Gaussian Channel Model For Microcellular Mobile Propagation," in European Signal Processing Conference, 2005.

[7] 3GPP, "TS 36.104 v8.0 (Release 8 series) BS radio Transmission and Reception," Available online: www.3gpp.org/tft/spects/html-info/36-series.htm, Accessed: 12th June, 2013.

[8] B. Sklar, Digital Communications. Englewood Cliffs, NJ: Prentice Hall, 1988.

[9] E. Alsusa, "Advanced Digital Communications," in Communication Engineering Lecture Notes: University of Manchester, 2009.

[10] T. S. Rappaport, Wireless Communications: Principle and Practice, 2nd ed.: Prentice Hall 2002.

[11] J. G. Proakis, M. Salehi, and G. Bauch, Contemporary Communications Systems using MATLAB: Thomson-Brooks/Cole, 2004.

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APPENDIX

Table I: Power Delay Profile ITU-R Model [4]

	Pedestrian A		Pedestrian B		Vehicular A		Vehicular B		Doppler Spectrum
Tap	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	Relative Delay (ns)	Average Power (dB)	
1	0	0	0	0	0	0.0	0	-2.5	Classic
2	110	-9.7	200	-0.9	310	-1.0	300	0.0	Classic
3	190	-19.2	800	-4.9	710	-9.0	8900	-12.8	Classic
4	410	-22.8	1200	-8.0	1090	-10.0	12900	-10.0	Classic
5			2300	-7.8	1730	-15.0	17100	-25.2	Classic
6			3700	-23.9	2510	-20.0	20000	-16.0	Classic