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Performance Analysis of different Interleaving Technique for M-QAM Modulation over Rayleigh Fading Channel in an Outdoor Environment with different Equalizers

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Abstract- In this paper we investigate the impact of using different block interleaving techniques with different equalizers for a digital communication system which uses MQAM (M=16) modulation technique to transmit information over Rayleigh faded AWGN channel in an outdoor environment. Interleaving technique which are considered here are Algebraic interleaver, Random interleaver, Matrix interleaver and Helical scan interleaver. Performance is analyzed in terms of bit error rate by MATLAB simulation. The different property values that is path delay, average path gain, maximum Doppler shifts, Doppler spectrum parameters etc are chosen carefully for the simulation of Rayleigh fading channel to show a realistic fading channel. Stepsize, forget factor etc for different adaptive algorithms used by decision feedback equalizer (DFE), linear equalizer (LE) are also chosen properly. All the analysis shows the use of interleaving technique increases the performance of communication system. Algebraic and Random interleaver have shown better performance for this considered communication system. Maximum likelihood sequence estimate (MLSE) equalizer provides best equalization for limiting signal dispersion and ISI.

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PERFORMANCEANALYSISOFDIFFERENTINTERLEAVINGTECHNIQUEFORMQAMMODULATIONOVERRALEIGHFADINGCHANNELINANOUTDOORENVIRONMENTWITHDIFFERENTEQUALIZERS

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I. Introduction

Mobile communications and wireless network have experienced massive growth and commercial success in the recent years. However, the radio channels in mobile radio systems are usually not amiable as the wired one. Unlike wired channels that are stationary and predictable, wireless channels are extremely random and time variant [1]. It causes multipath propagation. Multipath propagation in wireless communication system is a challenge. This phenomenon, caused by the arrival of multiple delayed copies of the transmitted signal at the receiver, results in intersymbol interference (ISI), severely distorting the transmitted signal at the receiver. This also causes time dispersion, attenuation, and phase shift, know as fading, in the received signal [2] . To transmit data from one location to another through wireless communication channel a lot of things have to consider such as modulation, encoding, filtering, equalization etc. For an effective communication all these things have to be done carefully. So appropriate technique choosing is very vital. M-ary signaling schemes are preferred over binary signaling schemes for transmitting digital information over band pass channels when the requirement is to conserve bandwidth at the expense of increased power [3]. This schemes are one of most efficient digital data transmission systems as it achieves better bandwidth efficiency than other modulation techniques and have higher data rate [4]. M ary modulation can enhance the power saving, especially in power-saving applications. There are many types of modulation techniques which are used for the transmission of information [5]. Different kinds of M-ary modulation techniques like MPSK, MDPSK, MQAM etc each of which offers benefits of its own [6]. The number of signals or number of M increases ($M \geq 0$, 1, 2,….,M) the error probability or more clearly the probability of Symbol error rate is increased [7].

In this paper MQAM modulation scheme is considered. BER performance using different interleaving techniques and equalizers over Rayleigh fading channel in an outdoor environment is analyzed by MATLAB simulation. These equalizers are maximum likelihood sequence estimate (MLSE) equalizer, decision feedback equalizer (DFE) and linear equalizer (LE). And the interleaving techniques we use are Algebraic interleaver, Random interleaver, Matrix interleaver and Helical scan interleaver. LE is used mainly for linear cases, DFE is used for non linear cases. But MLSE equalizer can be used for both cases [8]. For outdoor environments, path delays after the first are typically between 100 ns and 10 μs (i. e. between 1e-7 s and 1e 5 s) [25]. Here we have taken two paths of delay 1e-7s and 1e-5s. In practice, an average path gain value is a large negative dB value. However, computer models typically use average path gains between -20 dB and 0 dB. Here in this analysis the path gain is chosen -9dB and Doppler shift is taken 4HZ where The source moves

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at a speed 2.4 m/s and the carrier frequency is 500MHZ.

The rest of the paper is organized as follows. The communication system model is described in Section II. Section III describes the fading channel. Section IV Rayleigh fading channel. Section V discuss about Equalizers. Interleavers are discussed in SectionVI. Results are discussed in Section VII. Finally, Section VIII provides the concluding remarks of this work.

II. The Communication System Model

Communication system under consideration is shown In fig.1. Here a random signal using random bit generator is generated first. Then the generated binary data is encoded by a convolutional encoder of rate 1/2. After that the signal is interleaved by different interleavers and then converted into M-ary signal. This M-ary signal is modulated by M-ary modulation (16 QAM) scheme and transmitted through Rayleigh faded AWGN channel. At the receiver side the signal is equalized by equalizer (LQ, DFE & MLSE). After that, it is demodulated by a QAM demodulator. The demodulated symbols are converted into bits. The bit stream is de-interleaved. After that convolutional decoding is done to this signal. And the decoded signal is the desired output signal. The performance and characteristics of a channel depends on the choice of digital modulation schemes. Moreover, one scheme is said to be better than other depending on the channel, required levels of performance and the target hardware trade-offs [9].

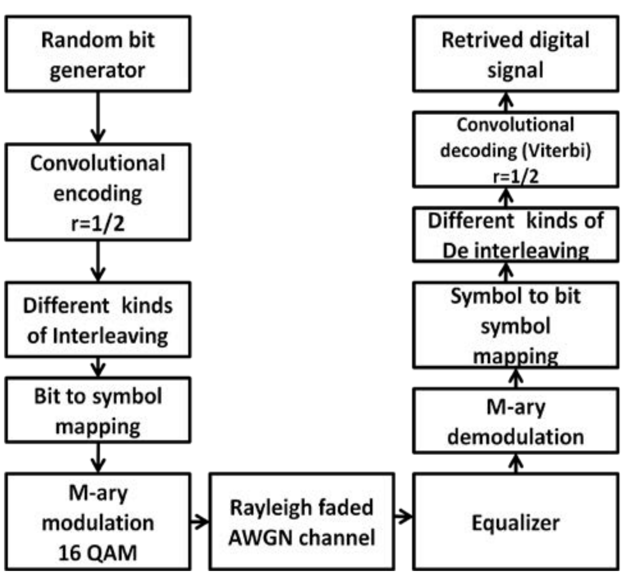

Figure 1 : Block diagram of digital communication system based on M-ary modulation scheme

III. Fading Channel

Fading is the deviation of the attenuation affecting a signal over certain propagation media. The fading may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel arises from the movement of the transmitter and receiver, commonly referred to as the time-varying effect or Doppler effect [12]. In a multipath fading channel, the transmitted signal arrives at the receiver via multiple paths. These paths generally arise via signal reflection from the ground, hills, buildings, and any other large structures. They also arise from signal diffraction via bending around the corners of buildings or sliding across rooftops. They also can arise via signal scattering from small objects. Each signal path results in a randomly delayed, attenuated, and phase- shifted copy of the transmitted signal. Examples of fading models for the distribution of the attenuation are Nakagami fading, Log-normal shadow fading, Rayleigh fading, Rician fading, Weibull fading etc. Here we will discuss about Rayleigh fading.

IV. Rayleigh Fading

The delays change in an unpredictable manner associated with different signal paths in a multipath fading channel and can only be characterized statistically. When there are a large number of paths, the central limit theorem can be applied to model the time-variant impulse response of the channel as a complex-valued Gaussian random process. When the impulse response is modeled as a zero mean complex-valued Gaussian process, the channel is said to be a Rayleigh fading channel. Rayleigh fading models assume that the magnitude of a signal that has passed through such a communications channel will vary randomly, or fade, according to a Rayleigh distribution. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals [13],[14].

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modeled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

Calling this random variable R, it will have a probability density function:

$$PR(r) = \frac{2r}{\Omega} e^{-r^2/\Omega} \quad , r \geq 0 \qquad (1)$$

Where, $\Omega = E(R^2)$

Often, a complex number is convenient to represent the gain and phase elements of a channel's distortion. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes. In this analysis, Jakes Doppler power spectrum has been considered. This spectrum model is actually due to Gans [20], who analyzed the Clarke-Gilbert model ([21], [22]). The Clarke-Gilbert model is also called the classical model. Jakes Doppler power spectrum applies to a mobile receiver. It derives from the following assumptions [23]: (i) The radio waves propagate horizontally. (ii) At the mobile receiver, the angles of arrival of the radio waves are uniformly distributed over [π, -π] [24]. At the mobile receiver, the antenna is omnidirectional (i.e. the antenna pattern is circular-symmetric).

V. Equalizer

Equalizer is a kind of filter which is used to control dispersion of received signal. It has a frequency characteristics that is inverse of that of transmission medium. This will restore higher frequency component and eliminate pulse dispersion [10]. There are three types of equalization methods commonly used :Maximum Likelihood Sequence (MLSE)- Detection - Optimal, but Impractical. The MLSE Equalizer uses the Viterbi algorithm to equalize a linearly modulated signal through a dispersive channel [11]. Linear Equalization - suboptimal, but simple. Non-Linear Equalization (DFE)- for severe ISI channels. Linear equalizers are simple to implement and are highly effective in channels where is the ISI is not severe (like the wired line telephone channel) [15]. Linear Equalizers are further classified into two types based on weight adaptation: Preset Equalizers, Adaptive Equalizers. DFE consists of a forward filter and a feedback filter formed. Once the receiver RX decisions on the received signal, the signal after its impact can immediately calculate and deduct. DFE using feedback system, so there is error propagation phenomena [16]. MLSE: In a single-carrier frequency-selective Rayleigh fading environment, assuming a time-invariant channel impulse response (CIR), the received symbols are described by [18, 19].

$$r_k = \sum_{j=0}^{L-1} h_j \, S_{k-j} + n_k \qquad (2)$$

Where Sk denotes the kth complex symbol in the transmitted sequence of N symbols chosen from an alphabet D containing M complex symbols, r_k is the kth received symbol, n_k is the kth Gaussian noise sample N (0, σ2) and hj is the jth coefficient of the estimated CIR [17]. The equalizer is responsible for reversing the effect of the channel on the transmitted symbols in order to produce the sequence of transmitted symbols with maximum confidence.

VI. Interleaver and Deinterleaver

Interleaving is the reordering of data that is to be transmitted so that consecutive bytes of data are distributed over a larger sequence of data to reduce the effect of burst errors. The use of interleaving greatly increases the ability of error protection codes to correct for burst errors. Many of the error protection coding processes can correct for small numbers of errors, but cannot correct for errors that occur in groups [26]. Interleavers consider in this paper are

Algebraic interleaver (algintrlv): Derives a permutation table algebraically, using the Takeshita-Costello or Welch-Costas method. Here Takeshita-Costello method is used.

Random interleaver (randintrlv): Chooses a permutation table randomly using the initial state input that you provide.

Matrix interleaver (matintrlv): Fills a matrix with data elements row by row and then sends the matrix contents to the output column by column.

Helical scan interleaver (helscanintrlv): Fills a matrix with data row by row and then sends the matrix contents to the output in a helical fashion. [27].

VII. Results & Performance Comparison

Performance analysis of different interleavers with different equalizer for MQAM modulation techniques under Rayleigh fading channel in outdoor environment implies in a FEC encoded digital communication system are shown through figure 2 to 6.

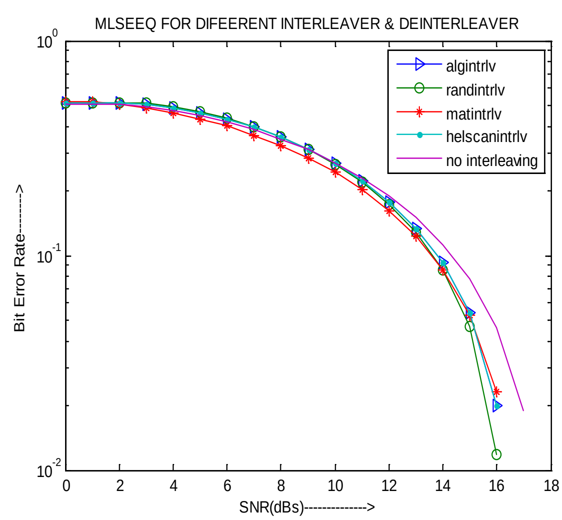

Figure 2 : Performance analysis for 16QAM signal with MLSE equalizer passing through multipath Rayleigh fading channel

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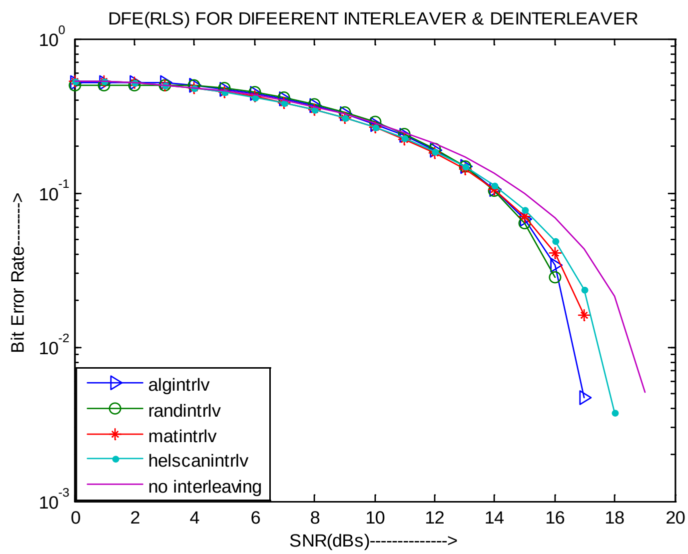

Figure 3 : Performance analysis for 16QAM signal with DFE(RLS) equalizer passing through multipath Rayleigh fading channel

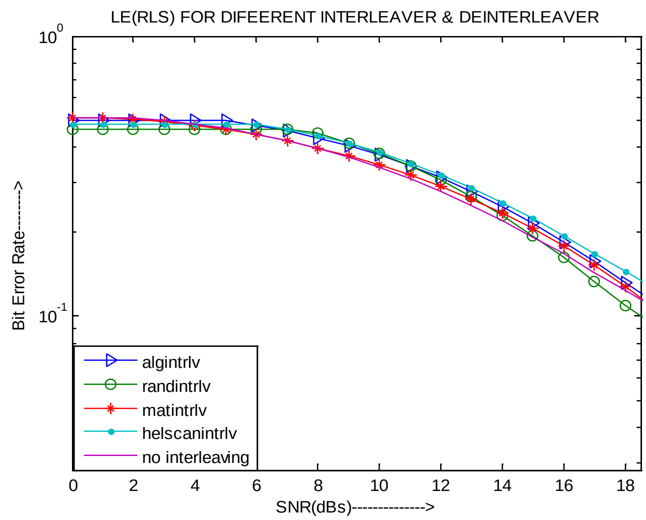

Figure 4 : Performance analysis for 16QAM signal with LE(RLS) equalizer passing through multipath Rayleigh fading channel

Figure 2 shows performance analysis for MLSE equalizer with different interleaving technique. At $10^{-1.5}$ BER the required SNR for algebraic, random, matrix, helical scan interleaver and the system without interleaver are 15.5dB, 15.2dB, 15.8dB, 16.1dB and 16.5dB respectively. It can be observed that for MLSE equalizer the BER for random interleaver and the system without interleaver are 0.0465 and 0.0776 at 15dB SNR. Thus BER performance using random interleaver is improved by 2.23dB compared to the system without interleaver.

In order to achieve $10^{-1.5}$ BER for DFE (rls) 16.1dB, 15.8dB 16.3dB ,16.5dB 17.5dB SNR are required by algebraic, random, matrix, helical scan interleaver and the system without interleaver respectively which is shown in Figure 3.

At 15dB SNR for DFE (rls) equalizer the BER are 0.0648 and 0.0996 for random interleaver and the system without interleaver respectively. Thus BER performance using random interleaver is improved by 1.93dB compared to the system without interleaver.

Figure-4 shows that LE (rls) equalizer could not achieve $10^{-1.5}$ BER for any of these interleaving technique considered SNR.

Figure 5 shows the performance of algebraic interleaver for MLSE, DFE (rls) and LE (rls) equalizer. At $10^{-1.5}$ BER the SNR of MLSE and DFE (rls) are 15.6dB and 16.2dB respectively. On the other hand Figure-6 shows performance analysis of random interleaver. 15.25dB and 15.8dB SNR are required by MLSE and DFE (rls) equalizer in order to achieve $10^{-1.5}$ BER. LE (rls) equalizer could not achieve $10^{-1.5}$ BER, it is mentioned above and also can be seen from the figures. It can be observed from figure 5 & 6 that MLSE equalizer is the best equalizer among these three that is MLSE, DFE (rls) and LE (rls).

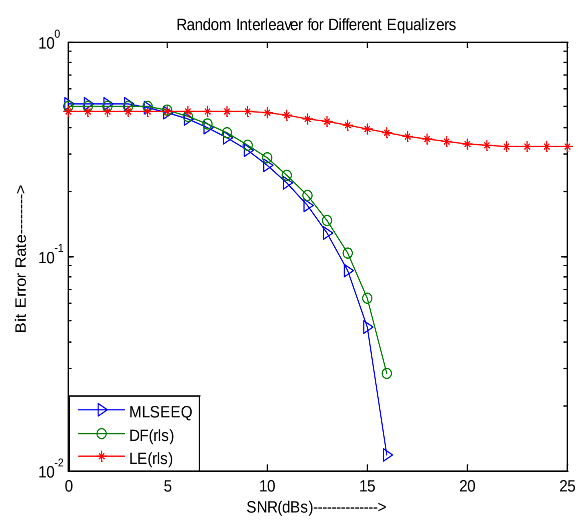

Figure 5 : Performance analysis of algebraic interleaver for different equalizers

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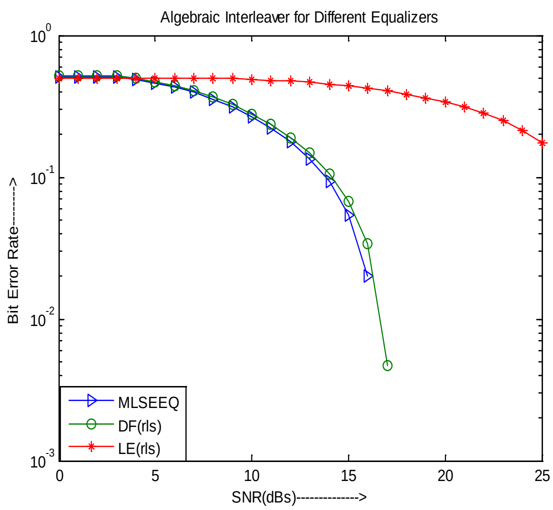

Figure 6 : Performance analysis of random interleaver for different equalizers

VIII. Conclusion

In this paper we have analyzed the performance of different types of interleaving techniques and equalizers for 16QAM modulation technique over a multipath Rayleigh fading channel in an outdoor environment. It is found that random interleaver shows better performance. The performance shown by algebraic interleaver is also good. And among the equalizers MLSE equalizer has shown the better performance than all.

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