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# A Novel Method to Improve Performance of Diffusive Molecular Communication Systems with On-Off Keying Modulation

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***Abstract: The Bit Error Rate (BER) of the diffusive molecular communication (DMC) systems employing on-off keying (OOK) modulation. We also analyze the BER of the OOK-modulated DMC systems with inter- symbol interference cancellation (ISIC). Our main motivation is to introduce alternative tools for analyzing and efficiently computing the BER of the DMC systems without or with ISIC. Specifically, for the OOK-modulated DMC systems without ISIC, we first derive an exact BER expression based on the Poisson modeling of DMC systems. Then, the Gaussian- and Gamma-approximation approaches are introduced to approximate the discrete Poisson distribution, and based on the approximation approaches, the corresponding BER expressions are derived.***

## I. INTRODUCTION

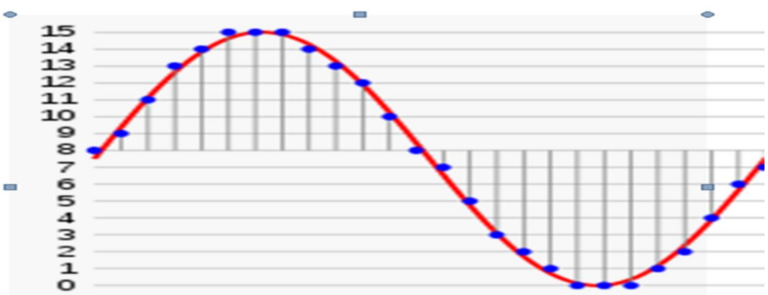
Diffusion-based molecular communication (DMC) is a promising technique for nano networks. The main objective of this paper is to evaluate the error performance of DMC employing pulse-based modulation scheme. We derive closed-form expressions for error probability using energy detection and amplitude detection techniques. The error performance model accounts for diffusion noise and inter symbol interference (ISI) effects. We compare the performance of both detection techniques along with investigating the effect of different parameters on error performance. We also evaluate the channel capacity of pulse modulated DMC.

## II. DIFFUSIVE MOLECULAR COMMUNICATION

Molecular communications systems use the presence or absence of a selected type of molecule to digitally encode messages. The molecules are delivered into communications media such as air and water for transmission. The technique also is not subject to the requirement of using antennas that are sized to a specific ratio of the wavelength of the signal. Molecular communication signals can be made biocompatible and require very little energy.

## III. MODULATION

In the diagram, a sine wave (red curve) is sampled and quantized for PCM. The sine wave is sampled at regular intervals, shown as vertical lines. For each sample, one of the available values (on the y-axis) is chosen. The PCM process is commonly implemented on a single integrated circuit called an analog-to- digital converter (ADC). This produces a fully discrete representation of the input signal (blue points) that can be easily encoded as digital data for storage or manipulation. Several PCM streams could also be multiplexed into a larger aggregate data stream, generally for transmission of multiple streams over a single physical link. One technique is called time- division multiplexing (TDM) and is widely used, notably in the modern public telephone system.




Sampling and quantization of a signal (red) for 4-bit LPCM

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## IV. DEMODULATION

To recover the original signal from the sampled data, a "demodulator" can apply the procedure of modulation in reverse. After each sampling period, the demodulator reads the next value and shifts the output signal to the new value. As a result of these transitions, the signal has a significant amount of high- frequency energy caused by aliasing. To remove these undesirable frequencies and leave the original signal, the demodulator passes the signal through analog filters that suppress energy outside the expected frequency range (greater than the Nyquist frequency ). The sampling theorem shows PCM devices can operate without introducing distortions within their designed frequency bands if they provide a sampling frequency twice that of the input signal. For example, in telephony, the usable voice frequency band ranges from approximately 300 Hz to 3400 Hz. Therefore, according to the Nyquist–Shannon sampling theorem, the sampling frequency (8 kHz) must be at least twice the voice frequency (4 kHz) for effective reconstruction of the voice signal. The electronics involved in producing an accurate analog signal from the discrete data are similar to those used for generating the digital signal. These devices are Digital-to-analog converters (DACs). They produce a voltage or current (depending on type) that represents the value presented on their digital inputs. This output would then generally be filtered and amplified for use.

## V. CHANNEL INTERLEAVER

Interleavers and Deinterleavers are designed and used in the context of characteristics of the errors that might occur when the message bits are transmitted through a noisy channel. To understand the functions of an interleaver/deinterleaver, understanding of error characteristics is essential. Two types are errors concern communication system design engineer. They are burst error and random error.

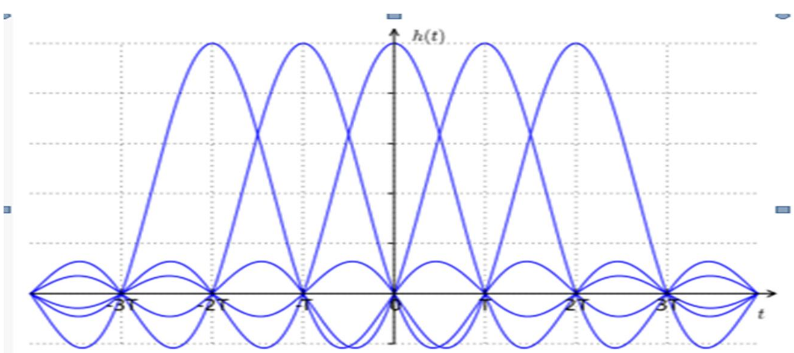
## VI. INTER-SYMBOL INTERFERENCE CANCELLATION

In telecommunication, intersymbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. The spreading of the pulse beyond its allotted time interval causes it to interfere with neighboring pulses. ISI is usually caused by multipath propagation or the inherent linear or non-linear frequency response of a communication channel causing successive symbols to "blur" together. The presence of ISI in the system introduces errors in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI, and thereby deliver the digital data to its destination with the smallest error rate possible. Ways to alleviate intersymbol interference include adaptive equalization and error correcting codes.

## VII. COUNTERING ISI

There are several techniques in telecommunication and data storage that try to work around the problem of intersymbol interference.

*A.* Design systems such that the impulse response is short enough that very little energy from one symbol smears into the next symbol.
*B.* Separate symbols in time with guard periods.
*C.* Apply an equalizer at the receiver, that, broadly speaking, attempts to undo the effect of the channel by applying an inverse filter.
*D.* Apply a sequence detector at the receiver, that attempts to estimate the sequence of transmitted symbols using the Viterbi algorithm.




Consecutive raised-cosine impulses, demonstrating zero-ISI property

## VIII. CONCLUSION

We have proposed a range of approaches for analyzing and to compute the BER of the DMC systems without or with ISIC, based on which exact and approximate BER expressions have respectively been derived. Our studies and comparison show that both the Gaussian- and Gamma-approximation are capable of providing near-accurate BER estimation, provided that the respective optimum thresholds are applied in detection. However, the optimum detection threshold estimated by the Gaussian- or Gamma-approximation is explicitly different from that given by the Poisson modeling, and hence it is practically not optimum. The efficiency of the system is analyzed thro Bit Error Rate Analysis.

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