The Effect of Partial Response Signaling Pulses under Wireless Communication Environments

Won-Ho Choi, Hyung-Yun Kong
School of Electrical, Electronic & Automation
Ulsan University

Abstract

In many radio communication environments, there is a special component, called inter-symbol interference (ISI), caused by multipath time delay of signal and ISI components impose limitations of the data transmission rate. In this paper, we consider signaling pulse shapes, called partial response signaling (PRS), for minimizing the effect of ISI and show the improvement of performance by applying one of the partial-response signaling (PRS) pulses to two types of receiver system under dependent noise environments through the Monte-Carlo computer simulations.

I. Introduction

The pulse amplitude modulation (PAM) is often used to convey digital information. The usual constraint on permissible *PAM* signal waveforms is that they should not cause *ISI*. Signal design based on this criterion can sometimes lead to the complete intolerance of timing errors or to incompatibilities with some channel characteristics. Some of these disadvantages can be removed with *PRS* (also known as correlative level coding) wherein the constraint on waveforms is relaxed so as to allow a controlled amount of *ISI*. *PRS* designs are based on the premise that since the *ISI* is known, its effect can be removed. One of the merits of the *PRS* is that the controlled *ISI* can be used to shape the system spectrum. Also, this spectral shaping can make the system less sensitive to timing errors. This allows practical *PRS* systems to transmit at the Nyquist rate, a feat not possible with ordinary *PAM*. The partial-response coding format has the further advantage that violations in the code can be used to monitor error performance or even to correct errors. On the negative side, *PRS* system using symbol by symbol detection possess reduced noise margins due to the fact that the superposition of signal waveforms causes the number of output levels to be larger than the number of input levels. Lender [1] first introduced the duo-binary *PRS* as a data transmission method and Kretzmer [2] catagorized the characteristics of several *PRS* schemes and compared them on the basis of speed tolerance and signal-to-noise ratio (SNR) degradation. Here, we took the duo-binary signaling pulse for computer simulations showing the improved performance when comparing to rectangular pulse in dependent noise channels. In general, wireless radio channels are characterized by fading caused by interference among multipath waves with different time delays and fading severely degrades the bit error rate (BER) performance. Diversity reception is one of the most powerful techniques to combat fading. In this paper, we consider phase combining(PC) method which can be approximated by maximal ratio combining (MRC) is used to develop the diversity system.

II. Signaling Pulse Shape

II-1. Modified Pulse Shape for Eliminating the Timing Jitter Error

The conditions on the signaling pulse shape under which *ISI* is either reduced or eliminated will be considered. Nyquist [3] showed that zero *ISI* may be achieved by choosing the pulse shape such that it has a nonzero amplitude at its center and zero amplitude at times, $t=\pm nT$, where T is the separation between successive transmitted pulses. The frequency characteristic represented by a rectangular pulse and defined by

$$p(w)=\begin{cases}1: & 0\le w\le \frac{1}{T}\\ 0 & : elsewhere\end{cases} \qquad (1)$$

is the only pulse satisfying such conditions when the transmission rate satisfies $\frac{1}{T}=2w_c$. However, such pulse has several serious problems;

1) difficulty in realizing a pulse with the rectangular characteristics.

2) the tails decay as $\frac{1}{t}$, a slight error in either the transmission rate or the sampling rate at the receiver, or a small timing jitter in sampling instants, can cause sufficiently large *ISI* for the scheme to fail.

Let us consider the method to solve 2) from instance describing the following;

The signal

$$p(t)=\frac{\sin w_c t}{w_c t},$$

$$P(w)=\begin{cases}\frac{\pi}{w_c} & : -w_c\le w\le w_c\\ 0 & : elsewhere\end{cases} \qquad (2)$$

and hence $R(w)=P(w)$ where $r(t)$ is the received signal assuming that the channel filter has ideal low pass filter with the same bandwidth of input signal, $p(t)$ which has the following property;

$$p(kT_0)=\begin{cases}1 & : k=0\\ 0 & : k\neq 0\end{cases} \qquad (3)$$

Since, in this case $r(t)=p(t)+p(t-T_0)+\cdots$ so long as the decisions are made at $t=kT_0$, there is no *ISI*. Thus the effect of *ISI* has been avoided by careful choice of input pulse $p(t)$. However, considerable error can be made, if the receiver makes slight timing error and $t=mT_0$ is not maintained exactly. Thus suppose the receiver makes timing jitter error and instead measures at times $t=mT_0+\varepsilon_m$ where ε_m represents a random jitter error. In that case the effects from the tail ends of *sinc* terms can add up to a large sum resulting in a appreciable quantity for the second error term in (4).

$$r(mT_0+\varepsilon_m)=a_m+\sum_{k\neq m}a_k \sin c(w_s(mT_0+\varepsilon_m))$$

(4)

Since *sinc(t)* decays so long as fast as $\frac{1}{t}$, this error due to timing jitter can be large and to minimize that it is best to make use of other pulses that preserve the zero crossing property in (3), but decays faster than $\frac{1}{t}$. Notice that the above design must be completed without increasing the bandwidth of the signal $p(t)$. On squaring the signal $p(t)$ in (2) we get

$$p_1(t)=p^2(t)=\sin c^2(w_1 t) \qquad (5)$$

Although, $p_1(t)$ decays as $\frac{1}{t^2}$ and has the same zero crossings as $p(t)$, it has twice the bandwidth compared to $p(t)$. Thus, if we start with bandwidth and amplitude $(2w_1, \frac{2\pi}{w_1})$ then it corresponds to the signal

$$p_2(t)=\sin c^2(w_1 t/2) \qquad (6)$$

Notice that $p_2(t)$ in (6) has the same bandwidth as $p_1(t)$ in (2) and it decays as $\frac{1}{t^2}$. However, the zero crossings of $p_2(t)$ are slower than that of $p_1(t)$. So far we consider the pulse design to eliminate the tail parts caused by timing jitter in the receiver and we assume that the channel model is consisted of three components which are direct, diffused and noise(called rician fading channel).

II-2. Signaling Pulse with Controlled ISI

Now we consider the signals with controlled *ISI*. The technique of introducing *ISI* in a controlled way so that receiver logic can cancel it out is called partial response or correlative coding. There is a whole class of partial response techniques [4]. However we will focus on the one, so called duo-binary signaling, where 'duo' implies the doubling of the transmission capacity when compared to the raised cosine-rolloff pulse ($\beta=1$ case). For this class of signals, we remove the constraint that there be no *ISI* at the sampling instants. Such condition lead to physically realizable pulses that are called partial response signals. The duo-binary pulse with the following characteristics belongs to this class of signals.

$$p(f)=\begin{cases}\frac{1}{B_c}\cos[\frac{\pi f}{2B_c}] & : \quad |f|\le B_c \\ 0 & : \quad elsewhere\end{cases} \qquad (7)$$

A duo-binary signaling system can be realized by using a duo-binary conversion filter. One disadvantage of the duo-binary signaling scheme is the error propagation in the recovered data due to an error in some past bit. This effect can be eliminated by using differential encoding at the transmitter and differential decoding at the receiver. In a duo-binary context, a differential encoder is called a precoder. Another disadvantage of the duo-binary system is that the spectrum is not zero at *dc*. This problem can be corrected by using a *modified duo-binary* technique that was introduced by Lender [1]. The pertinent signaling can be generated by using a modified duo-binary. Letting $T=1/(2w_c)$, the resulting pulse characteristic is ,

$$p(f)=[2je^{-jwT}]\begin{cases}\frac{1}{B_c}\sin[\frac{\pi f}{B_c}] & : \quad |f|\le B_c \\ 0 & : \quad elsewhere\end{cases} \qquad (8)$$

III. Discussion of Simulation Results and Conclusion Remarks

Through the computer simulations, we plotted the performances representing the comparison of Pe according to different signaling pulse shape. Fig.1-Fig.4 show the performance of system which adopted duo-binary pulse as a signaling pulse with single sample detector (or with conventional equalizer) is much better than that of system using rectangular pulse in dependent noise(gaussian & rician) cases.

Fig.1 Comparing the Pe of single sample detector using different pulse shape for dep gaussian noise

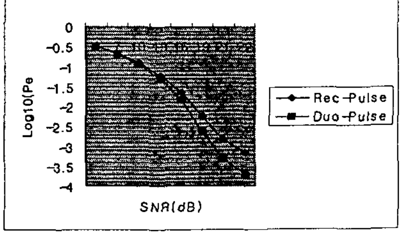
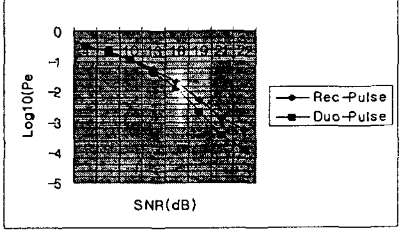


Fig.2 Comparing the Pe of single sample detector using different pulse shape for dep rician noise



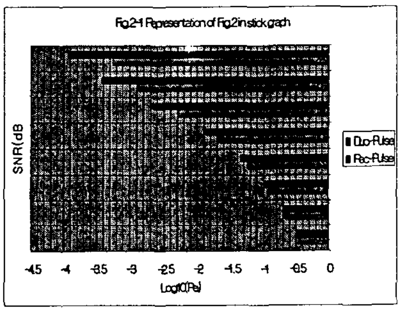


Fig.3 Comparing the Pe of single detector with conventional equalizer according to different pulse shape for dep gaussian noise

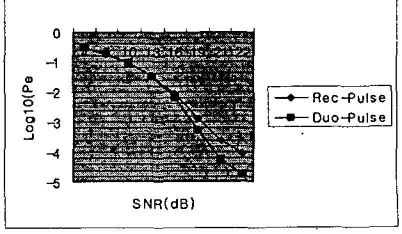
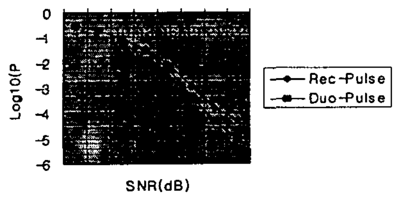


Fig.4 Comparing the Pe of single detector with conventional equalizer using different pulse shape for dep rician noise



To find coefficients value of the non-linear equalizer, we used training mode. Through the figures, we conclude that the effects of ISI will be smaller for the duo-binary pulse than for the rectangular pulse under any noise conditions.

IV. References

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