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Research paper

Impact of Pre-and Post-Equalization on the Performance of PNC

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Abstract

The work presented considers a Physical Layer Network Coded (PNC) communication which is affected by Intersymbol Interference (ISI) due to Rayleigh fading channel. A pre-equalizer filter configured to combat the ISI is considered at the end nodes. The relay uses the Amplify and Forward (AF) strategy. The signal in the Multiple Access (MAC) phase is amplified at the relay and forwarded to the receiving nodes. The signal received by the end nodes in the broadcast (BC) phase is subjected to post-equalization by a receiver filter configured to overcome ISI. The performance of the PNC with only pre-equalizer applied, only post-equalization applied and the combined effect of pre-equalizer and post-equalizer is simulated .Simulation results indicate that the performance of PNC when only pre-equalizer applied , only post-equalization is applied are not much varying but better than the no equalization case. But the combined effect of pre-and post-equalization is much improved.

Keywords: *PNC, Two-way relay channels, Amplify-Forward protocol, Sum-BER, Maximum sum-rate.*

1. Introduction

With an aim of increasing the spatial diversity by cooperation of nodes and extending the coverage area without increasing the transmitted power there has been an intense research in the field of relay networks [1]. In wireless networks based on relay, more than one relay work in coordination to send the data between a source and destination in the scenario when the two nodes are out of coverage of each other [2]. Under such situations relay nodes play a key task and also the way the data is processed at the relay is going to impact the overall outcome of the process. The relay can be a most simple AF relay to the most complex Decode and Forward (DF).AF is preferred when simplicity is of prime importance but it has an inherent drawback of noise amplification which makes DF more appealing when the noise power at the relay is high as the received signal is decoded and re-encoded before forwarding it to the destination which results in removing the effect of noise [3].

Bidirectional relays are contradictory to the one way relaying where each relay is designed to perform bidirectional communication between two transceivers at the same time[6][8]. In bidirectional relaying the relay performs the processing of the signal it received from the two transceivers and then sends this signal back to the two transceivers so that by self interference cancellation it has the information sent by the other node. This protocol of bidirectional relaying is called as physical-layer network coding (PNC) and the two phases of communication are known as multiple access (MAC) phase and the broadcast (BC) phase. The important factors which are responsible for the propagation delay for a bidirectional relay network are the processing delay at the relay and the propagation delay due to sources to the relay channel and the channel from the relay to the sources. This propagation delay can be varying for different paths which results in frequency selectivity of the end to end channel which in turn gives rise to Intersymbol interference (ISI).Also transmitting the signal at a high modulation rate can be a major cause of ISI since increase in the modulation rate results in increase of the signals bandwidth. In the scenario of signal's bandwidth becoming more than the channel bandwidth, the channel starts to add distortion to the signal.

The band limited nature of all the practical channels is the reason that reduces the maximum data rate because they attenuate the higher frequency components of the signal. This results in increase of rise and fall time of each symbol which increases the period of each symbol which poses the chances that each symbol will interfere with the next coming symbols causing ISI.

The Nyquist Zero ISI condition is met by appropriately designing the pulse shaping filter, transmit filters, the channel and the receiver filters. But channel itself is not capable of meeting the zero ISI condition then the possible options are to use the transmit filters and the receive filters so that the overall response meets the zero ISI condition. And these transmit and receive filters are known as equalizers.

The objective of equalizers is to remove intersymbol interference (ISI) and additive noise and make it as low as possible. Mitigating the effect of the inter symbol interference (ISI) by applying appropriate filtering operation is known as the equalization technique [5].Spectral shaping of the transmitted signal to reduce the spectral bandwidth plays an important and is achieved by the virtue of pulse shaping. The part of out of band power is reduced by spectral shaping. Pulse shaping filters reduce the ISI effectively.

In the communication process the data sent by the transmitter has to be correctly detected by the receiver. The receiver has to sample the received signal at the right instant of time so that the probability of an incorrect decision is as low as possible. Hence this indicates that shape of the pulses be in a way that they do not interfere during the sampling instant. This objective can be met if the pulse shape exhibits zero crossing at the sampling instant of all pulse intervals excluding its own and the shape of the pulse has to be selected in such a way that its amplitude decays quickly beyond the pulse interval.Pulse shaping filters used to be designed using analog filters prior to introducing digital filters. As the analog filters have many inherent disadvantages like aging tolerance range whereas the digital filter is purely dependent on the filter coefficients. Digital pulse shaping filters are an inevitable part of many digital communication systems. Digital implementation of raised cosine filter is most widely used .A digitally implemented filter is constrained to the conditions of a Nyquist system which says that the filter sampling rate must be double than that of the spectrum of the input signal to avoid aliasing. Digital pulse shaping filter which operates at a sampling rate of f_s , then the highest input bandwidth must be limited to f_s /2.The conventional wireless communication process the equalization is performed at the receiving end i.e. at the mobile station rather than doing it at the base station transmitter which complicates the receiver design and also increases the power utilization [9]. To overcome this some of the previous works have used pre-equalization at the transmitter. The receiver equalization may face performance deterioration due to noise enhancement which is not an issue in pre-equalization performed at the transmitter by pre-equalizing the signal stream digitally before transmitting

Pre-equalizing in PNC has been studied in several previous works. In [10][11] linear equalizer is applied at the relay with two of the source nodes using transmit filters .Source node data being modulated with binary phase shift keying (BPSK) modulation with the relay works by DF strategy. A predistortion based equalizer is studied in [12]. A predistortion is intentionally introduced in one of the outgoing information and this is taken advantage in relay to perform the equalization at the relay. In [13] decision feedback equalization (DFE) and Tomlinson Harashima precoding (THP) are studied. The transmit filter is designed to generate an identical channel impulse response from source to relay. The work mainly concentrates on non linear equalization techniques and their impact on the performance of PNC. The previous works have considered the DF relay strategy which is more complex as compared to the AF strategy. Moreover if the equalization is introduced at the relay then it will further increase the processing complexity of the relay. As discussed it is optimal to reduce the receiver complexity and introduce the equalization at the transmitter and complexity of the relay is kept low by using AF strategy. The performance of transmitter based pre-equalization , post-equalization, the combined effect of pre-and post-equalization and also the performance without any equalization are compared in the work presented.

2. System Model

The present work in this paper is based on a bidirectional relay channel with source *A* sending data *A* ,Source *B* sending data *B* by using of relay R based on AF protocol as the two source nodes are not in the coverage area of each other there is no direct link between them. The proposed system model is shown in fig.1. Here we are considering three different implementations. With a pre-equalization of the modulated data by a pulse shaping filter. The second implementation considers a combined effect of pre-equalization of the modulated data and then post-equalization at the receiver end. These two implementations are compared with the results of non-equalized system performance.

Let .x_A and x_B represent the information symbols sent by node *A* and *B* correspondingly with power P_A and P_B. The modulation used is QPSK .The channels are Rayleigh type between node *A* and the relay, and node *B* and the relay are represented as *h* and *g* respectively. The additive white Gaussian noise at node *A*, and *B* and the relay are denoted by n_A~CN $(0.\sigma_A^2)$, n_B~CN $(0.\sigma_B^2)$,n_r~CN $(0.\sigma_r^2)$ correspondingly. The signal obtained at the relay from node *A* and *B* are multiplied by a gain *G* and is then multiplied by power P_r.

Let $\bar{\gamma}_A = \dfrac{P_A}{\sigma_r{}^2}, \bar{\gamma}_B = \dfrac{P_B}{\sigma_r{}^2}, \bar{\gamma}_{r,A} = \dfrac{P_r}{\sigma_A{}^2}, \bar{\gamma}_{r,B} = \dfrac{P_r}{\sigma_B{}^2}$

The two nodes in the first time slot modulate data using QPSK modulation and then the modulated signal is subjected to pre-equalization using pulse shaping filter and this data is transmitted concurrently to the relay node. The relay node amplifies and forwards the received signals towards two source nodes in the second time slot. The signal sent by the relay to the source nodes *A* and *B* is initially subjected to self interference cancellation and then demodulated .In the other implementation the signal received in the consequent time slot is subjected to post equalization by using an oversampling based digital finite impulse response (FIR) filter.

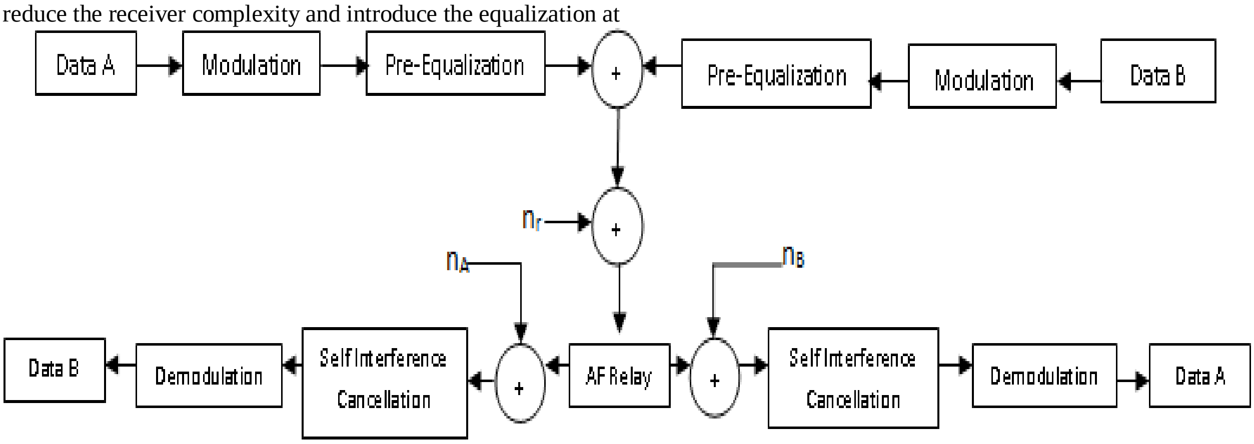

Fig. 1: Block diagram of proposed work

The relay received signal in the first time slot is written as

$$r = \sqrt{P_A} h x_A p + \sqrt{P_B} g x_B p + n_r \tag{1}$$

Where *p* is the pulse shaping digital FIR filter .Once the self-interference term is cancelled ,the signal received at node A and B are correspondingly given by,

$$y_A^* = G\sqrt{P_r}\sqrt{P_B} hg x_B + G\sqrt{P_r} h n_r + n_A \tag{2}$$

$$y_A^* = G\sqrt{P_r}\sqrt{P_A} gh x_A + G\sqrt{P_r} g n_r + n_B \tag{3}$$

The output SNR at node A and B are respectively given as

$$\gamma_{A,2TS} = \frac{\bar{\gamma}_{r,A}\bar{\gamma}_B |g|^2 |h|^2}{\bar{\gamma}_{r,A}|h|^2 + \frac{1}{G^2\sigma_r^{\ 2}}} \quad (4)$$

$$\gamma_{B,2TS} = \frac{\bar{\gamma}_{r,B}\bar{\gamma}_A |h|^2 |g|^2}{\bar{\gamma}_{r,B}|g|^2 + \frac{1}{G^2\sigma_r^{\ 2}}} \quad (5)$$

The gain is given as

$$G = \frac{1}{\sqrt{P_A|h|^2 + P_B|g|^2 + \sigma_r^{\ 2}}} \quad (6)$$

For the case with combined effect of pre-equalization and post-equalization the digital prefilter *H(w)* with the signal bandwidth *B*, symbol rate 1/T and sampling rate l/Ts as parameters is specified. The received samples are initially processed by sampler with higher than Nyquist rate followed by a digital filter which produces a subset of samples processed at

rate l/Ts that, on the average, precisely one sample per symbol duration T is generated.

$$H_L\left(e^{jwT_s}\right) = \begin{cases} 1, & |w2\pi| < B \\ 0, & else \end{cases}$$

3. Simulation Results

The performances of the proposed work are as follows. Fig.1.shows the sum BER of the TWRC PNC when the transmitter filter is used as a pre-equalizer once the data is modulated

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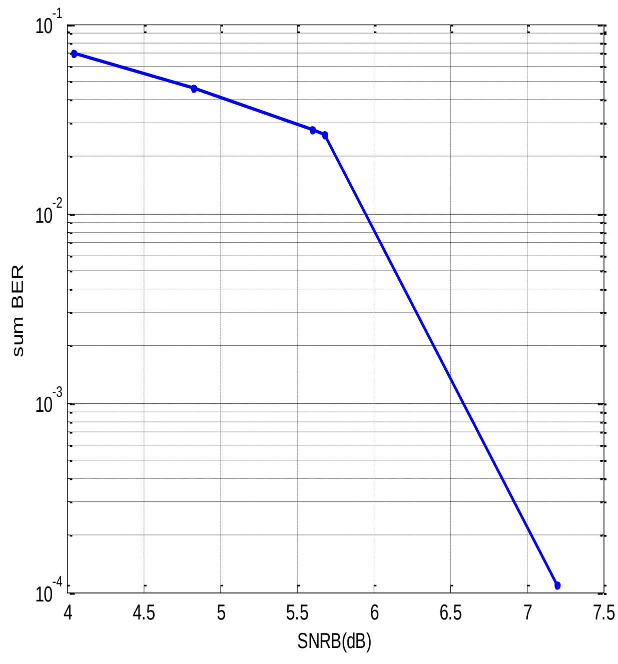

Fig. 1: Sum BER with pre-equalizer

Fig.2. shows the outcome of the TWRC PNC when the combination of transmitter filter is used as a pre -equalizer and a digital filter based post-equalization is applied to the data received from the relay to both the sources.Sum-BER is simulated for various SNR values. This procedure of filtering the received signal to cancel the ISI caused by the channel impulse response indicates that there is an improvement in the outcome in terms of error rate performance and the performance is achieved without increasing the processing delay at the relay as it can worsen the performance.

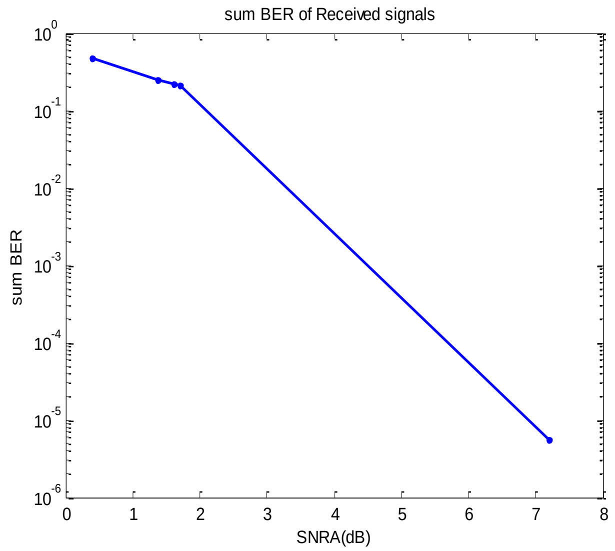

Fig. 2: Sum BER with pre-and post-equalization.

Fig.3. represents the performance of the TWRC PNC without any equalizer at the receiving nodes.

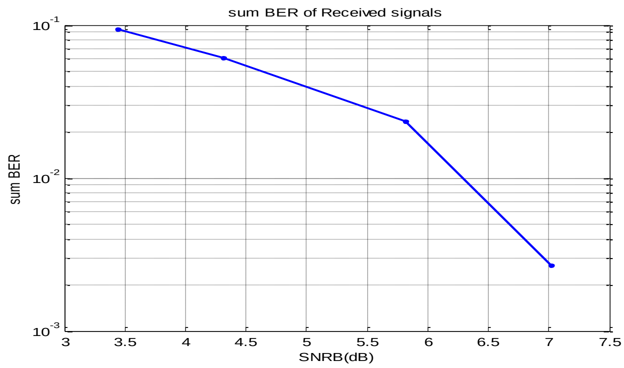

Fig. 3: Sum BER without Equalizer.

Fig. 4 represents the outcome of the TWRC PNC in terms of max sum rate for the above mentioned methods.Intersymbol interference is a restraining factor for transmission rate in a wireless communication system. It can be overcome by filtering based linear equalizers. The max sum rate considering the equalized SNR shows an improvement when compared to those of the un -equalized case. The results indicate that there is a gain in throughput at low SNR due to equalization and at high SNR there is not much gain in the throughput. .

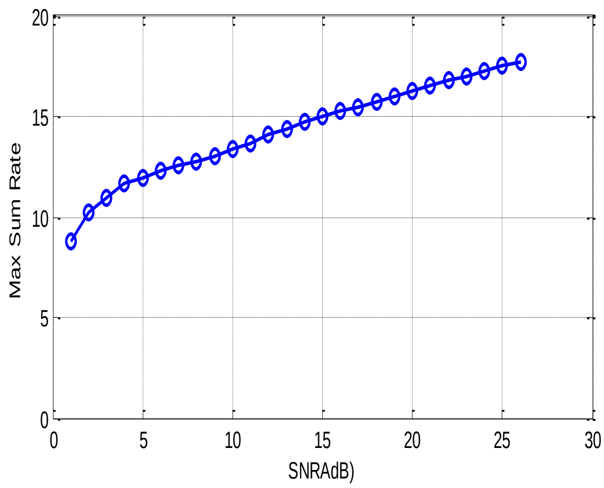

Fig. 4: Max-sum rate with Pre- equalizer

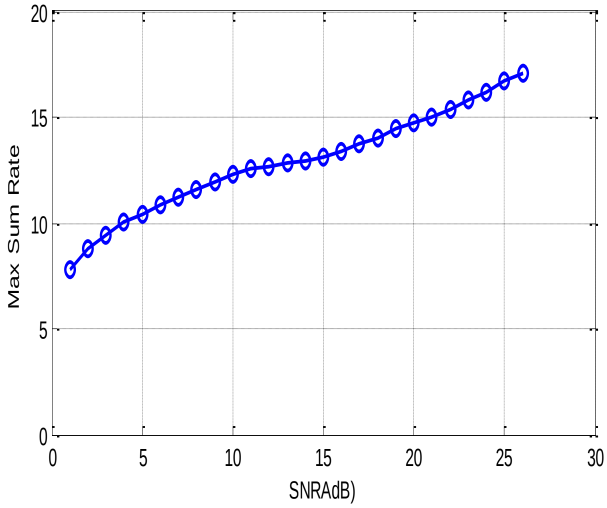

Fig. 5: Max-sum rate with pre-and post-equalization Equalizer

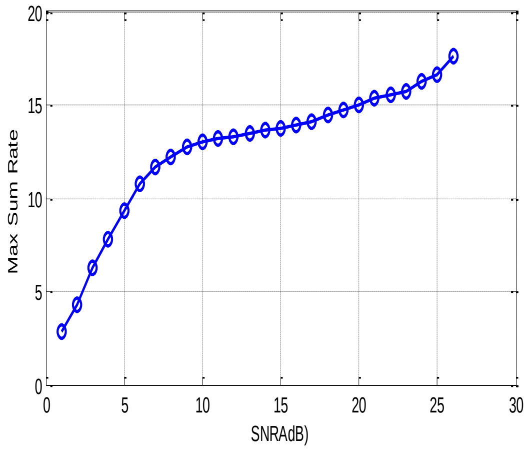

Fig. 6: Maximum sum rate- without Equalizer

4. Conclusion

A PNC communication is considered. We have simulated the impact of three different equalization techniques i.e. pre-equalization, post-equalization, pre-and post-equalization. The outcome of the PNC is simulated in terms of BER and max sum-rate. It is implicit from the results that there is an improvement in results for pre-equalization, post equalization compared to un-equalized case. But there is not much variation in the performance among each other. Further it is observed that the effect of joint pre-and post-equalization is more prominent in the BER results. Hence for controlling and analyzing the parameters like ISI, pulse shaping of a signal at base-band is a prominent way.

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