BPSK-Turbo Codes with Spiral Curve Phase Precoding for Wireless-ISI Channel

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Abstract

In this paper, a proposed wireless transmission model by concatenation of turbo codes and Spiral curve phase precoding is introduced. It is a novel ISI-combating method for BPSK signals through multipath fading channel. Simulation results show that Spiral curve phase precoding with binary turbo codes achieves the better gain at high SNR compared to that of Viterbi equalizer with the same turbo code scheme.

Keywords

ISI, Turbo Code, Wireless Communications

I. Introduction and Background

In wireless communications, intersymbol interference (ISI) is one of the major impairments which reduce system efficiency dramatically. Efficient equalization techniques have been devised to decrease this ISI effect such as Viterbi or maximum likelihood equalizer (VE), optimum or sub-optimum soft output equalizer (OSE,SSE)[1], decision feedback equalization(DFE) and *pre*-equalizer by using *precoding* technique. The first well known version of that precoding is Tomlinson-Harashima (TH) precoding [2][3] which precoded on only amplitude modulated signal. Consequently, Spiral curve phase precoding [4] has been devised to avoid the disadvantage of TH-precoding of dealing with only that amplitude. This is done by proposing Spiral-based phase precoding method. In this paper, a proposed wireless-transmission model by concatenation of turbo codes [5] with Spiral curve phase precoding on *BPSK* signal through multipath fading channel is introduced. This proposed method is a novel combined technique of powerful coding and *pre*-equalization method. It aims to decrease ISI effect in wireless communications.

II. Proposed Method

The binary transmission model with full-duplex two signal links is proposed in Figure 1. In the forward link binary turbo encoder transfers encoded signal of input sequence d_k and to be the binary codeword. As a result, a complex coded symbol $\vec{m}_i = Ae^{j\beta_i}$ is obtained, where A is constant amplitude and β_i is phase of the i^{th} information signal. After interleaving to avoid burst error of fading, signal symbol $\vec{S}_i$ co-operating with the channel estimated parameters $\vec{I}_i$ of the reverse link from the slow fading channel in the same data frame of TDD multiplexing systems, are used to compute precoded signal $\vec{P}_i = Ae^{j\theta_i}$ (where θ_i is the precoding phase). The channel fades so slowly such that it is assumed to be the time invariant over two adjacent frames of the forward and reverse link. In addition, the channel impulse response can be modeled as a linear and time-invariant over two adjacent data frames so that the radiation patterns are reciprocal in both forward and reverse links [4]. Moreover, channel parameters are estimated perfectly on the reverse link. Due to the limitation of size and power consumption of the mobile unit, precoding is used only at the transmitter of base station.

At the receiver, signal $\vec{R}_i'$ from the multipath Rayleigh fading channel is detected. The received information carrying phase β_i' is re-generated by using the detection regarding spiral curve precoding. To have a proper information for turbo decoder, this paper also presents a technique to calculate soft-decision data in the Logarithm of Likelihood Ratio (LLR) format, $\Lambda(d_i)$, from β_i'. Finally, this data is de-interleaved and passed to the turbo decoder to recover for the original binary data d_i'.

III. Modified Spiral Curve Detector

Pre-equalization by Spiral curve phase precoding [4] has been devised to combat ISI for phase modulated signal based on Spiral curve technique. This Spiral has been modified and improved for achieving the optimum performance in the previous work of [6]. Therefore, that latest version is used in this work.

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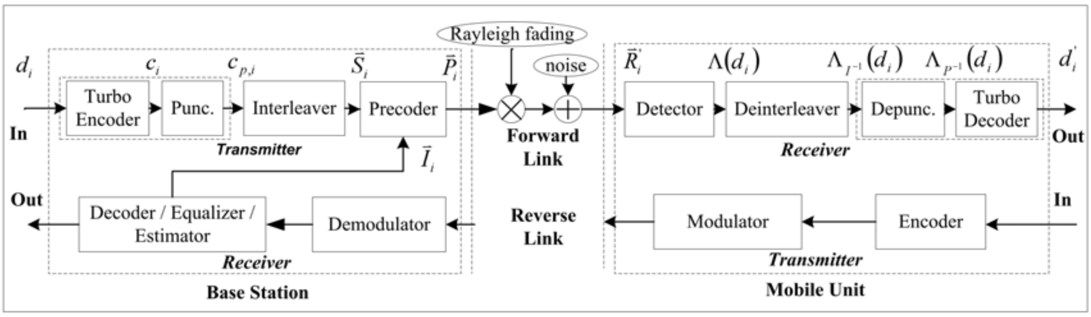

Figure 1 Proposed Model of Turbo Codes on *Precoded*-BPSK Signals

The operation of the ordinary Spiral curve detector to calculate the received information will be done by using the relation of the received signal $\vec{R}_i' = r_i' e^{j\phi_i'}$ in Spiral curve equation [4] to compute the received information carrying phase β_i' by

$$\beta_i' = \phi_i' + \psi_0' + (r_i' - C)\pi \tag{1}$$

where r_i' is the received signal amplitude with phase ϕ_i', ψ_0' is the ISI vector's phase, and *C* is the Spiral curve constant. However, the output of the ordinary Spiral curve detector will be in β_i'-form of the information signal and it must be modified to generate the soft-decision data in the LLR format for turbo decoder which defined by

$$\Lambda(d_i) = \log\left[\frac{P\{d_i = 1 \mid \vec{R}_i'\}}{P\{d_i = 0 \mid \vec{R}_i'\}}\right] \tag{2}$$

From the assumption as in [6], If *C* is equal to 1/a$_0$, then β_i' can be always detected at the detector perfectly. Moreover, ISI is combated by precoding prior to passing signal to the channel. Hence, β_i' is a *simplified* Gaussian random variable with zero mean and variant σ_β^2. As a result, a *posteriori* probability $p(\vec{S}_i = \vec{x} \mid \beta_i')$ of the BPSK-signal ($S_{d_i=0}$, $S_{d_i=1}$) with amplitude *A* and phase $\beta_{d_i=0}$ or $\beta_{d_i=1}$ can be calculated by

$$p(\vec{S}_i = \vec{x} \mid \beta_i') = \left(1/\sqrt{2\pi\sigma_\beta^2}\right)\exp\left(-\left|\beta_i' - \beta_x\right|^2/(2\sigma_\beta^2)\right) \tag{3}$$

where $\vec{x}$ is the reference of BPSK-Signal. Thus, LLR is computed by

$$\Lambda(d_{i,k}) = \log\left[\frac{p(S_i = S_{d_i=1} \mid \beta_i')}{p(S_i = S_{d_i=0} \mid \beta_i')}\right]$$

$$= \log\left[\frac{(1/\sqrt{2\pi\sigma_\beta^2})\exp\left(-\left|\beta_i - \beta_{d_i=1}\right|^2/(2\sigma_\beta^2)\right)}{(1/\sqrt{2\pi\sigma_\beta^2})\exp\left(-\left|\beta_i - \beta_{d_i=0}\right|^2/(2\sigma_\beta^2)\right)}\right] \tag{4}$$

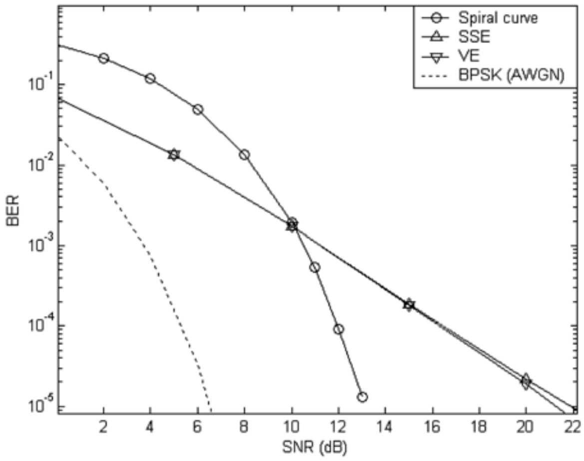

Figure 2 Performance comparison of uncoded-BPSK with different equalization techniques

The variant σ_β^2 of β_i' is calculated from

$$\sigma_\beta^2 = \frac{\sum_{i=1}^{L}\left(\left|\beta_i' - \beta_s\right|^2\right)}{L} \tag{5}$$

where *L* is the number of blocksize and β_s is the nearest signal phase to each of β_i'.

IV. System Performance

In this paper, simulation is carried out to study the performance of the proposed model. The simulated ISI channel is modeled by two equal strength rays of Rayleigh fading on the τ - spaced discrete-time model where the delay $\tau = |\tau_1(t) - \tau_0(t)|$ is one symbol period *T*. Doppler effect is not taken into account.

First, performance comparison of pure equalization (VE and SSE) and precoding on uncoded BPSK signal is presented in Figure 2. At high signal-to-noise ratio (SNR), it is obvious that Spiral curve phase precoding gives the best performance compared to those of VE and SSE which 9 dB of gain is achieved at BER of 10E-5. Next, in Figure 3 system performance with the potential of turbo codes is presented. Constitution codes is [37, 21] with rate of ½ and its parameters are 1024 bit-block size, and with block-external interleaver. Results confirm that the proposed technique of Spiral precoding with turbo code is the best case compared to those of the conventional equalization technique (VE).

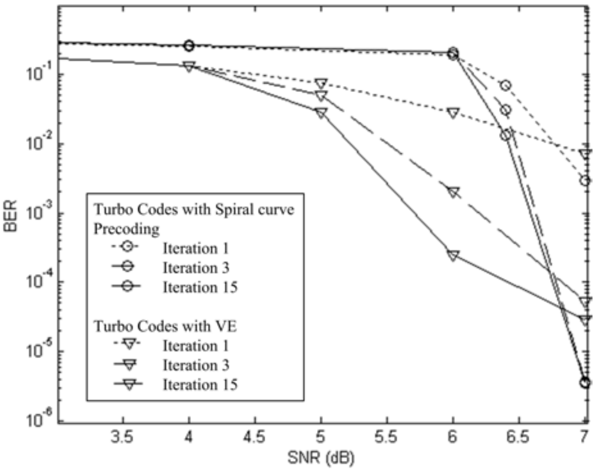

Figure 3 Performance comparison of Turbo Codes G = [37, 21] with *Pre* and *Post*-equalization (VE) on BPSK signal

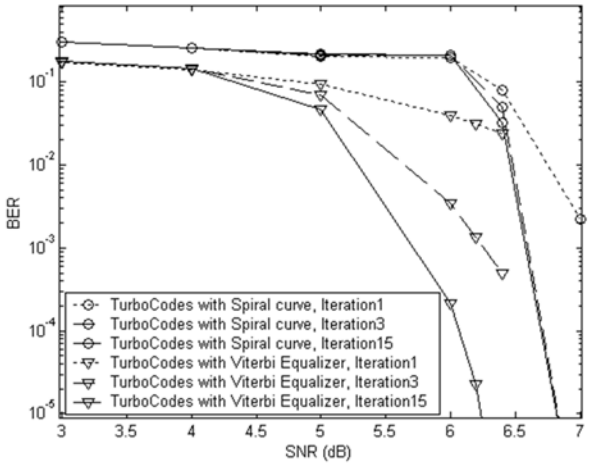

Figure 4 Performance comparison of Turbo Codes G= [23, 35] with *Pre* and *Post*-equalization (VE) on BPSK signal

Furthermore, they are also much better than performances of pure equalization in Figure 2. However, because σ_{β}^{2} is computed from $\beta_i^{'}$ of the ordinary Spiral curve detection which assumed to be equivalent-Gaussian random variable, then the system performance might be poor at low SNR. This effects shows in Figure 4. In this case, constitution code of [23, 35] is used. Results present to the poor performance of spiral curve compared to those VE with the same turbo code scheme, specially, at low SNR. Therefore, system conditions of constitution code, blocksize, precision of computing σ_{β}^{2} in Figure 4. should be re-designed optimally in the future works.

V. Conclusion

In this paper, a proposed transmission model by concatenation of turbo code and Spiral curve phase precoding on BPSK signal is presented. It is a successful method to combat ISI effect for signal transmission through the multipath fading of wireless communication channel. In the future, the optimum condition using turbo codes with Spiral curve precoding including the extension to work with higher *M-ary* PSK signaling will be considered.

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