Mixed Phase-Precoding Method with Turbo Codes for Wireless-ISI Channel Applications

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***Abstract*-This paper presents a novel precoding method for BPSK signals through multipath fading channel. It is named as "*mixed* phase-precoding method". This technique is developed mixing on the principle of spiral curve phase precoding and with a dimension partitioning technique. In order to apply this method for applications with turbo code, a specific detector is also proposed. Simulation results show that concatenation of turbo codes and *mixed* phase-precoding achieves a better gain compared to that of the ruled precoder method of spiral curve with the same turbo coding schemes.**

***Index Terms*- *Pre*-Equalization, Turbo code, ISI**

I. INTRODUCTION

In wireless communications, intersymbol interference (ISI) is one of the major impairments that reduces system efficiency dramatically. Thus, powerful *pre*-equalization techniques have been devised to decrease ISI effect. The first well-known version of those precoding techniques is Tomlinson-Harashima (TH) precoding which is used to precode amplitude modulated signals only [1][2]. Thus, Spiral curve-phase precoding [3] has been developed to avoid the disadvantage of TH-precoding. This was done by proposing *Spiral*-based phase precoding method. In addition, another precoding technique, *Dimension Partitioning* [4], has been published with the same purpose.

In previous works [5][6], a proposed wireless-transmission model by concatenation of turbo code [7] and a "modified" version of Spiral curve precoding on BPSK and QPSK signal through multipath fading channel, was introduced. That was also included the use of another interesting precoding technique of Dimension Partitioning. Simulation results show that concatenation of "modified" Spiral curve phase precoding with turbo codes is a successful method to combat ISI effect for signal transmission through the multipath fading channel. However, this previous model was noted that it still performs poor at low signal to noise ratio (SNR) region. It, therefore, should be re-designed with a better approach to achieve the optimal system performance.

This paper presents a novel version of phase precoding that developed on the principle of spiral curve phase precoding with dimension partitioning technique. It is named as "*mixed* phase-precoding method". Moreover, a specific detector designed for turbo codes is also proposed. In section II, the proposed transmission model is presented. Next, The precoding and detection algorithm for *mixed* phase-precoding are shown in section III and section IV respectively. In section V, a specific detection for turbo decoder is proposed. Finally, their simulation results are discussed in section VI.

II. THE PROPOSED TRANSMISSION MODEL

Figure 1 shows the proposed transmission model with two-duplex two signal links which the forward link direction receives digital input sequence d_i. Each input sequence is encoded by using binary turbo encoder at the rate 1/2 and gives the code word $(c^0_{p,i}, c^1_{p,i})$ as an output. This code word is passed to the signal mapper to provide appropriate format of signal for precoding method. As a result, a complex coded symbol $\vec{S}_i = Ae^{j\beta_i}$ is obtained, where A is a constant amplitude and β_i is phase of the i^{th} information signal. After that, this signal sequence is interleaved and passed to the precoder in order to create the precoded signal $\vec{P}_i = Ae^{j\theta_i}$ (where θ_i is the precoding phase). Due to the channel for this system fades slowly, the channel-estimated parameter $\vec{I}_i$ which is used for this operation can be investigated from the process of the reverse link in the same data frame of TDD multiplexing systems. That is 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. 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 $\vec{R}_i'$ that passed from the multipath Rayleigh fading channel, is detected and computed by the Logarithm of Likelihood Ratio

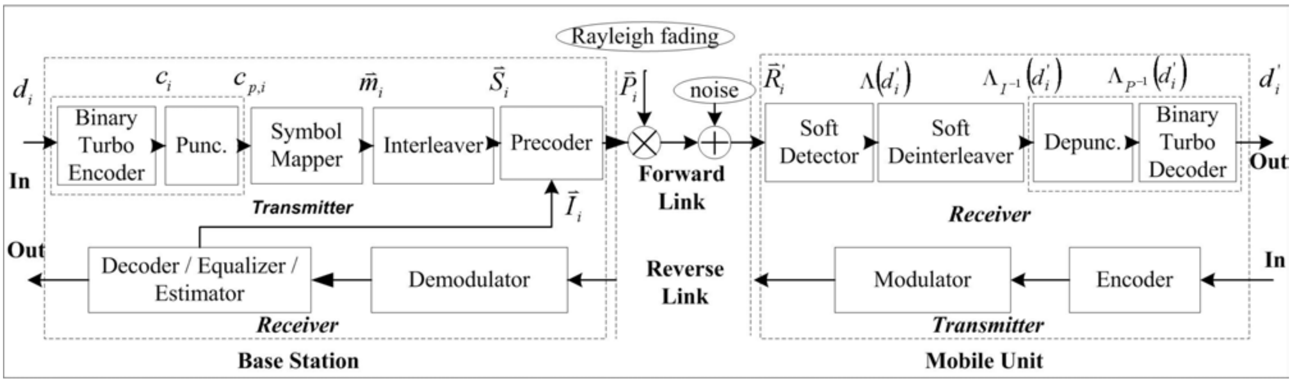

Fig. 1 Proposed Wireless Transmission Model

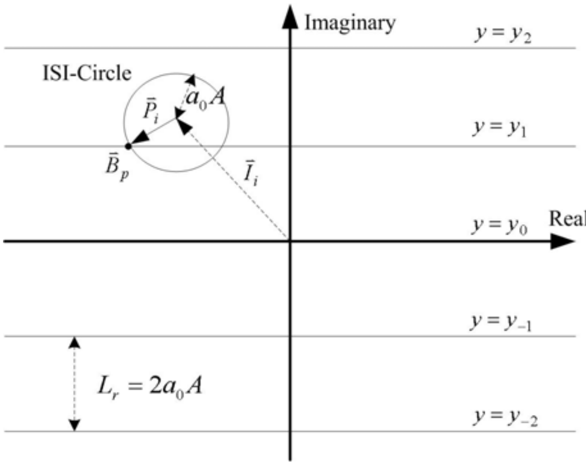

Fig. 2 *Mixed* Phase-Precoding Structure

(LLR); $\Lambda(d_i')$, defined as

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

Subsequently, the sequence of this parameter is deinterleaved and passed to the turbo decoder to recover information data d_i'.

III. *MIXED* PHASE-PRECODING

If spiral curve precoding [3] is used in this system, the received signal $\vec{R}_i' = r_i' e^{j\phi_i'}$ at time t_i will be computed by using spiral curve equation to obtain

$$\beta_i' = \phi_i' + \left(\frac{r_i'}{A} - 1\right) C\pi \tag{2}$$

However, when $\vec{R}_i'$ is very close to the center of spiral curve, effect of noise becomes larger. Thus, their operations should be modified to avoid from this case. An approach method could be done by changing the precoding algorithm to have the suitable results for all of ISI cases, such as using of the concept of Dimension Partitioning [4]. This paper presents an alternative precoding method called "*mixed* phase - precoding".

The operations of *mixed* phase-precoding is based on a function of a group of lines, paralleled to the real-axis in the signal space, as shown in Figure 2. Each line is separated equally by L_r and their imaginary part y_z is

$$y_z = zL_r + \frac{\beta_i L_r}{2\pi} \quad ; \; z = ..., -2, -1, 0, 1, 2, ... \tag{3}$$

where β_i is phase of the information signal and z is an integer number referred to a line of y is y_z. Due to each line of this function will be used for the decision at the detector, they are called "the decision line". Basically, the precoded signal for this schemes is calculated by determine roots of equation (3) and the ISI-circle, centered at $\vec{I}_i$ and with radius $a_0 A$, denoted by

$$(a_0 A)^2 = (\mathrm{Re}(\vec{I}_i) - x)^2 + (\mathrm{Im}(\vec{I}_i) - y)^2 \tag{4}$$

where (x, y) is the position of a point on the signal space. Respectively, a_0 and φ_0 is amplitude and phase distortion of the first path fading, $\mathrm{Re}(\vec{I}_i)$ and $\mathrm{Im}(\vec{I}_i)$ is a number of real and imaginary of $\vec{I}_i$. Consequently, only one root $\vec{B}_p$ will be selected. It is the desired received signal which is subtracted by $\vec{I}_i$ to be the precoded signal or

$$\vec{P}_i = Ae^{j\theta_i} = \vec{B}_p - \vec{I}_i \tag{5}$$

Finally, phase of this precoded signal is subtracted by φ_0 to compensate from phase distortion of the first path fading. The value of L_r plays an important role. In this paper, L_r is set to $2a_0 A$ to prevent from the case that there is no existing root of equation (3) and (4).

IV. PHASE DETECTING ALGORITHM

From precoding algorithm described in section III, the precoded signal is generated by using relationship between the desired received signal's imaginary part and β_i as in (3). Therefore, at the detector, the received information carrying phase $\beta_i^{'}$ can be calculated by.

$$\beta_i^{'} = (\mathrm{Im}(\vec{R}_i^{'})\,\mathrm{mod}(L_r))\frac{2\pi}{L_r} \quad (6)$$

where $\mathrm{Im}(\vec{R}_i^{'})$ is a number of imaginary of $\vec{R}_i^{'}$ and $\mathrm{mod}(x)$ is a function of modulo operation. In order to use this precoding method with turbo decoder, another kind of detecting algorithm is also developed. This algorithm for application with BPSK-signal is presented in the next section.

V. APPLICATIONS WITH TURBO CODES

The detected data from the detector in the form of LLR can be done by computing condition probabilities $P(\vec{S}_i = Ae^{j\beta_{d_i=0}} \mid \vec{R}_i^{'})$ and $P(\vec{S}_i = Ae^{j\beta_{d_i=1}} \mid \vec{R}_i^{'})$ from $\vec{R}_i^{'}$ at each time. They are probabilities of $\vec{S}_i$ which their phase are $\beta_{d_i=0}$ and $\beta_{d_i=1}$ respectively. When error distribution of the received signal is assumed as *Gaussian* distribution with zero mean and variance σ_N^2, this condition probability can be calculated by

$$P(\vec{S}_i = Ae^{j\beta_{d_i=x}} \mid \vec{R}_i^{'}) = \frac{1}{\sqrt{2\pi\sigma_N^2}}\exp\left(\frac{-\left(\mathrm{Im}(\vec{R}_i^{'}) - \left(z' L_r + \frac{\beta_{d_i=x} L_r}{2\pi}\right)\right)^2}{2\sigma_N^2}\right) \quad (7)$$

where $z^{'}$ is an integer number of the selected decision line which can be computed by

$$\left|\mathrm{Im}(\vec{R}_i^{'}) - \left(z' L_r + \frac{\beta_i L_r}{2\pi}\right)\right| \le L_r / 2 \quad (8)$$

Finally, $\Lambda(d_i^{'})$ is then calculated from

$$\Lambda(d_i^{'}) = \log\left[\frac{P(\vec{S}_i = Ae^{j\beta_{d_i=1}} \mid \vec{R}_i^{'})}{P(\vec{S}_i = Ae^{j\beta_{d_i=0}} \mid \vec{R}_i^{'})}\right] \quad (9)$$

VI. SIMULATION RESULTS

In this paper, simulation is carried out to investigate performance of the proposed model. ISI channel is modeled by two equal strength rays of Rayleigh fading on the τ - spaced discrete-time model

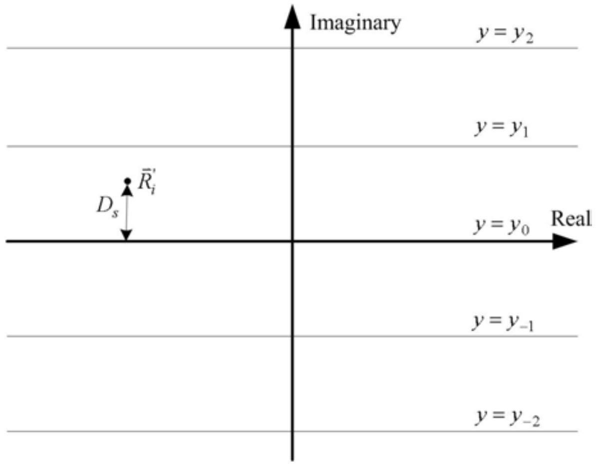

Fig. 3 Phase detection

where the delay $\tau = |\tau_1(t) - \tau_0(t)|$ is one symbol period *T*. Doppler effect is not taken into account. In Figure 4, performance comparison of Spiral curve and *mixed* phase-precoding on uncoded-BPSK signal is presented. Amplitude of the transmitted signal is set to unity, Spiral curve constant C for Spiral curve precoding is $1/a_0$, and L_r of *mixed* phase-precoding is $2a_0A$. From simulation result, it is obvious that *mixed* phase-precoding has the better performance compared to that of Spiral curve.

The performances of the concatenation of turbo codes with modified Spiral curve and *mixed* phase-precoding on BPSK signal are shown in Figure 5. Turbo code for this simulation is $[23_8, 35_8]$, rate 1/2 (throughput 1 bit/sec/Hz) with 1024 bit per block and the internal interleaver is a pseudo-random interleaver. The external interleaver works in block style and decoder for this simulation is the Log-MAP turbo decoder. Parameters for each precoding are as used in the previous case. Their results at iteration 1, 3 and 18 show that performance of turbo code with *mixed* phase-precoding achieves the better gain compared to that of Spiral curve with the same turbo coding scheme.

VII. CONCLUSION

This paper presents a novel precoding method that developed on the principle of Spiral curve phase precoding and Dimension Partitioning. It's called *mixed* phase-precoding and designed to use with phase modulated signal. For applications with turbo codes, an another kind of detecting algorithm that generates soft-decision data in the format of LLR is also proposed. Their simulation results on BPSK signal show that it is a suitable precoding algorithm for using of both with and without turbo coding schemes. Evidently, this work shows the successful invention of new phase precoding method. Its application for wireless ISI channel by concatenation with turbo code achieves dramatically performance improvement.

In the future, improvement on performance of this schemes at low SNR region, and under other channel condition such as Nakagami will be studied.

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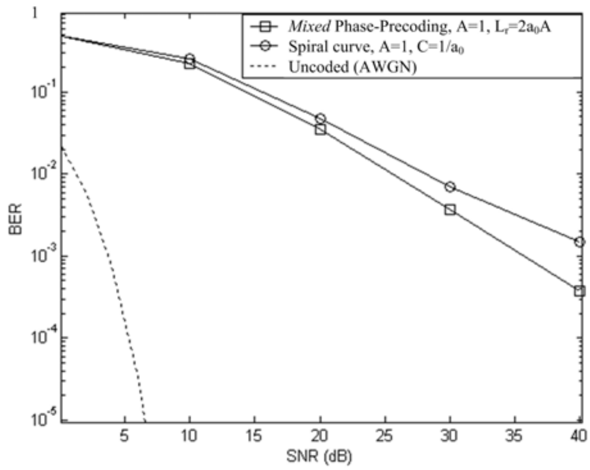

Fig. 4. Performance Comparison for Uncoded-BPSK Signal

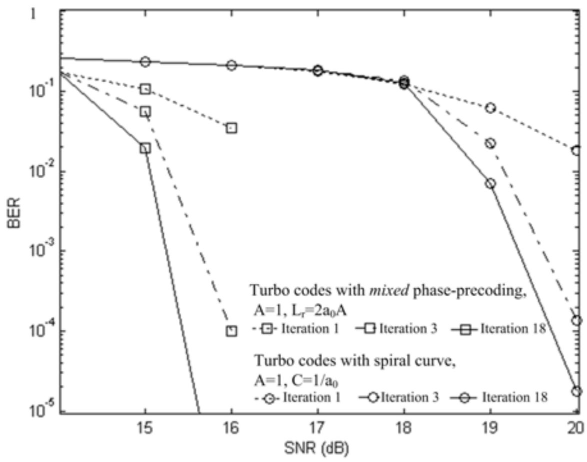

Fig. 5. Performance of Concatenation of Turbo Codes with Two Types of Precoding