Error Performance of UWB-MIMO system according to channel detection methods

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Abstract - In this paper, binary pulse-position modulation (BPPM) time-domain (TH) ultra-wideband (UWB) system is applied to multiple input multiple output (MIMO) system using vertical bell lab layered space-time (V-BLAST) structure to achieve high-data-rate communications. This UWB-MIMO system and its receivers are analyzed, and its BER performances are evaluated. In the received various MIMO detection algorithms such as zero-forcing (ZF), ZF-ordered successive interference cancellation (OSIC), minimum mean-square-error (MMSE), MMSE-OSIC and maximum likelihood (ML) are comparatively studied.

1. Introduction

UWB-MIMO systems have been considered as promising candidates for wireless communication systems. However, the BER performance of these systems is significantly affected by the channel estimation errors.

2. System Model

The system model of the UWB-MIMO system is shown in Figure 1. The transmitted signal from the $i$-th transmit antenna is given by $s_i(t)$, where $i = 1, 2, \ldots, N_t$. The received signal at the $j$-th receive antenna is given by $r_j(t) = h_{ij} s_i(t) + n_j(t)$, where $h_{ij}$ is the channel matrix, and $n_j(t)$ is the additive white Gaussian noise (AWGN).

The transmitted signal is amplitudemodulated using BPPM with a symbol rate of $R_s$. The transmitted symbols are mapped to the taps of the impulse response of a receive filter with a finite length of $L$. The received signal is then sampled at a rate that is at least twice the symbol rate.

2.1 Channel Model

The channel is modeled as a flat-fading channel with independent and identically distributed (i.i.d.) Rayleigh fading. The channel is assumed to be frequency-selective and the channel coefficients are assumed to be constant over a symbol interval.

2.2 Zero Forcing

Zero Forcing (ZF) is a simple but effective method to combat the channel estimation errors. In ZF, the receiver estimates the channel coefficients and uses them to perform linear equalization.

2.2.1 ZF Algorithm

The ZF algorithm can be formulated as follows:

$$\hat{h}_{ij} = \frac{r_j(t)}{s_i(t)}$$

where $\hat{h}_{ij}$ is the estimated channel coefficient between the $i$-th transmit antenna and the $j$-th receive antenna.

2.2.2 ZF Performance

The BER performance of the ZF algorithm can be evaluated using the symbol error rate (SER) given by

$$P_e = \frac{1}{2} e^{-\frac{E_s}{N_0}}
$$

where $E_s$ is the symbol energy and $N_0$ is the noise power density.

2.3 ZF-Ordered Successive Interference Cancellation (OSIC)

In OSIC, the channel coefficients are estimated first, and then the interference is canceled in a sequential manner. The performance of OSIC is better than that of ZF for high SNR conditions.

2.4 Minimum Mean-Square-Error (MMSE)

The MMSE detector is a linear detector that minimizes the mean-square error between the estimated and the true symbols. The MMSE detector is more complex than ZF and OSIC, but it provides better BER performance.

2.5 MMSE-OSIC

MMSE-OSIC is a combination of the MMSE and OSIC detectors. It provides better BER performance than ZF and OSIC, but it is more complex.

2.6 Maximum Likelihood (ML)

The ML detector is the optimal detector in the sense of minimizing the probability of symbol error. However, it is computationally intensive and is not practical for real-time systems.

3. Conclusion

In this paper, the BER performances of various MIMO detection algorithms such as ZF, OSIC, MMSE, and ML were evaluated. The results showed that the MMSE and OSIC detectors provide better BER performance than ZF and ML, but they are more complex.

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References


2.2.2 Minimum Mean-Square Error

minimum mean-square error (MMSE) decoding is performed using receive antennas and signal estimation is performed and using solution $\mathbf{x}$ is found as follows:

$$z_i = (\mathbf{H}_i^* \mathbf{R}_i^{-1/2}) \mathbf{R}_i^{1/2} \mathbf{x}_i$$

$\mathbf{z}_i$ and $\mathbf{H}_i$ and $\mathbf{R}_i$ and $\mathbf{x}_i$ are the input, channel response matrix, received signal covariance matrix, and the estimated symbol vector, respectively.

2.2.3 Successive Interference Cancellation

V-BLAST system is much more complex in terms of interference cancellation than O-SIC. The interference is suppressed independently of each received signal. Here, the interference cancellation is performed sequentially.

The iterative process can be described as follows:

1. Initial estimate of $\mathbf{x}_i$ using $\mathbf{H}_i$ and $\mathbf{R}_i$

$$\mathbf{G}_i = \mathbf{G}_i \mathbf{R}_i^{-1/2} \mathbf{R}_i^{1/2} \mathbf{x}_i$$

2. The interference is subtracted from the received signal $\mathbf{z}_i$.

$$\mathbf{z}_i = \mathbf{z}_i - \mathbf{G}_i \mathbf{H}_i^* \mathbf{R}_i^{-1/2} \mathbf{R}_i^{1/2} \mathbf{x}_i$$

3. The process is repeated until convergence.

2.2.4 Maximum Likelihood

ML detection is the most robust method for estimating the transmitted symbol. However, the computational complexity is high.

The maximum likelihood estimate is given by:

$$\hat{\mathbf{x}} = \arg \max \{ P(\mathbf{z}_i | \mathbf{x}_i) \}$$

2.3. System Performance

The performance of the MIMO system is evaluated by calculating the bit error rate (BER) and the signal-to-noise ratio (SNR). The BER is defined as the ratio of the number of erroneous bits to the total number of bits transmitted.

$$BER = \frac{N_{err}}{N_{tot}}$$

where $N_{err}$ is the number of erroneous bits and $N_{tot}$ is the total number of bits transmitted.

The SNR is defined as the ratio of the signal power to the noise power.

$$SNR = \frac{P_{signal}}{P_{noise}}$$

where $P_{signal}$ is the signal power and $P_{noise}$ is the noise power.

The BER performance of the MIMO system is evaluated using computer simulations. The simulation results are compared with theoretical predictions and good agreement is observed.