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Accomplishment of time turnaround ultra wide band system for Rayleigh channel

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Abstract:
Nowadays UWB (Ultra Wide Band) technology is gaining importance in PANs. Using UWB technology short distance communication with higher data rates can be achieved. Time reversal (TR) system is a system that is described by the recent occurred sample. UWB technology with the combination TR technique makes the system less dependent on channel parameters and the system is completely described by the channel impulse response (CIR). Channel impulse response can be extracted using deconvolution method. In this, transmitter is trained with a pre-defined signal before the actual transmission of the data through the channel.

Keywords: UWB, channel impulse response, CLEAN algorithm

Introduction

Time reversal technique in time domain is the counter part of phase conjugation in frequency domain. In time reversal technique a message is prepared such that it appears at a particular time at a particular location in space and nowhere else. In time reversal technique, a signal can be focused at a targeted receiver using the concept of pre-filtering. This concept of pre-filtering is achieved by using a time-reversed complex conjugate of the CIR extracted at the receiver as a channel pre-filter at the transmitter. This paper deals with the theory and applications of time reversal technique in UWB technology for Rayleigh channel and the results are compared with that of AWGN channel.

Block Diagram

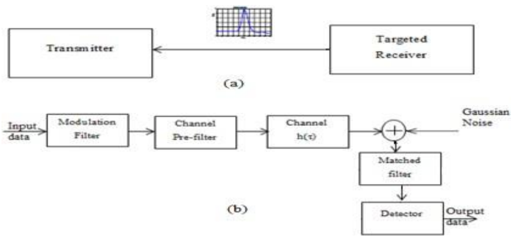

Figure 1: (a) Training module (b) Implementation module

Clean Algorithm

Clean algorithm is a deconvolution algorithm to extract channel impulse response. Deconvolution is the process of reversing the effect of convolution on recorded data. Deconvolution is mainly used to find the solution to the equation of the form where y may be considered as the output of a particular system which is the convolution of two signals.

$$y = x * h$$

Here x and h are the two signals which were convoluted to produce the signal y.In this project to transfer data from one place to other using TR UWB system we need to have knowledge of the impulse response. The extraction of this impulse response is done by using deconvolution technique called as CLEAN algorithm. Using this algorithm the transmitter is trained by an impulse like signal that is transmitted by the target receiver. Now the output signal at the transmitter is used to extract the impulse response. Here the impulse response is considered to be effected by the noise in the form of input signal to produce the output signal. The effect of the input signal on the impulse response is to be cleaned to extract the impulse response. Once the output is free from the effects of the input signal then the resultant output is equivalent to the impulse response of the system. The received signal at the output of the receiver can be given as

$$y(t) = h(t) \otimes x(t)$$

Here the result of the convolution with x(t) is considered as noise and it is removed from y(t). This is done by combining the input signal again to the output signal in the form of correlation functions. In this process the input signal is cross correlated with the signal y(t) and the peaks of the auto correlation function and cross correlation functions are to be subtracted from the cross correlation function. Here the subtraction demonstrates the idea behind cleaning. The auto correlation function of x and cross correlation of x and y are expressed as below

$$R_{xx}(\tau) = \int_{-\infty}^{\infty} x(t)x(t+\tau)dt$$

$$R_{xy}(\tau) = \int_{-\infty}^{\infty} x(t)y(t+\tau)dt$$

The peaks of the auto correlation function and cross correlation function are subtracted from the cross correlation function by using the following equations

$$h_k(\tau) = h_{k-1}(\tau) + A_k\delta(\tau - t_k)$$

$$h_0(\tau) = 0$$

$$b_k(\tau) = b_{k-1}(\tau) - A_k R_{xx}(\tau - t_k)$$

$$b_0(\tau) = R_{xy}(\tau)$$

where

$$|b_{k-1}(t_k)| = \operatorname{argmax}_{\tau}|b_{k-1}(\tau)|$$

$$A_k = b_{k-1}(t_k)$$

To stop the algorithm a threshold has to be incorporated. The threshold T is defined such that if $|A_k| \leq T\max|R_{xy}(\tau)|$, the algorithm is stopped. This clean algorithm is robust to the noise in the received data which is not the case in frequency domain deconvolution techniques.

Implementation

The channel impulse response obtained using clean algorithm is used in the implementation of TR UWB system as channel pre filter. Input data is modulated using quadrature amplitude modulation (QAM). QAM is used as it is suitable for short range communication. The modulated output is applied as input to the channel pre-filter which is derived from the time reversed complex conjugate of the channel impulse response. The output of the pre-filter is transmitted through Rayleigh channel. The output of the channel which is mixed with noise is applied to matched filter whose impulse response is derived from the input signal. The transmitted data is extracted from the output of the matched filter using a decision device.

RESULTS

In this section the performance of the TR UWB system is evaluated using simulation of BER. In the first case the simulation is done for AWGN channel and the results are compared with that of Rayleigh channel. For this the minimum target BER is taken as 10^{-3}. The number of symbols per simulation is considered as 10^4 and the number of bits per symbol is considered as 52.

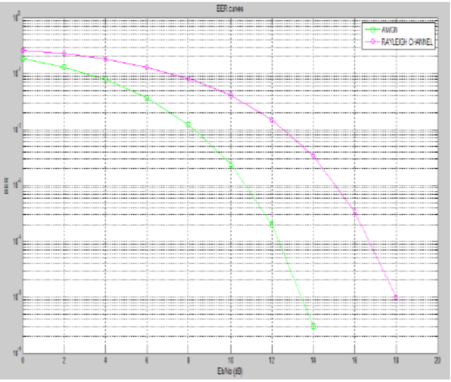

Figure 2: BER plots

For a fixed value of signal to noise ratio, TR UWB system with AWGN channel as medium has low value of BER compared to with Rayleigh channel. Amount of noise added is more in Rayleigh channel compared to AWGN channel due to multipath fading effect. In that condition also TR UWB system gives better performance.

Table 1: Comparision of $E_b/N_o$for different BERs

BER	E_b/N_o (dB)	
	TR system with AWGN channel	TR system with Rayleigh channel
10^{-1}	3	7
10^{-2}	8	13
10^{-3}	11	15
10^{-4}	12	16
10^{-5}	13	17
10^{-6}	14	18

Table 2: Comparision of BER for different values of E_b/N_o

Permitted BER		
E_b/N_o (dB)	TR system with AWGN channel	TR system with Rayleigh channel
3	$1x10^{-1}$	$2x10^{-1}$
5	$5x10^{-2}$	$10x10^{-2}$
7	$2x10^{-2}$	$9x10^{-2}$
10	$2x10^{-3}$	$4x10^{-2}$
12	$2x10^{-4}$	$2x10^{-2}$
13	$1x10^{-6}$	$3x10^{-3}$

Conclusion

The main objective of this thesis is to study and investigate the theory of time reversal technique in UWB technology. The BER performance of TR system is studied. Channels such as AWGN channel, Rayleigh channel are characterized with respect to the performance metric BER. In Rayleigh channel TR UWB system requires higher value of signal to noise ratio compared to that of value required in AWGN channel for a particular BER due to multipath fading effect.

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