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High Data Rate UWB System Design

Mr J.K. Ravan[*1], Dr. Mrs S.R. Chougule[2]
[*1]Assistant Professor, Dhananjay Mahadik Group of Institutions, India
[2] Principal. Bharati Vidyaeeith Collegg of Engg. Kolhapur, India
jitendr.k.ravan@gmail.com

Abstract

UWB technology is a serious candidate for the new emerging Wireless Personal Area Network (WPAN). In this context UWB is expected to provide very high data rates ≥ 500Mbps for short range communication. Many physical layer schemes have been proposed to address such rates on the wireless medium. Historically pulse based systems have been first proposed as the main modulation technique for UWB. The pulse based modulations inherently occupies a very large bandwidth (several GHz), which is required due to the very low emitting power. This technique is currently considered for low data rate in the sensor network context, but seems to be discarded for high data rate transmissions. Another physical layer, Multi Band Orthogonal Frequency Division Modulation (MB-OFDM), has been proposed within the IEEE802.15.3a task group. This technique is based on the well known OFDM scheme which allows good immunity towards multipath channels. In this proposal, only a 500MHz band is used at a given time, and a frequency hopping technique spreads the signal over several GHz. Finally, Direct Sequence Spreading (DSS) has also been proposed in the UWB framework (DSUWB). In this scheme, the data are spread over few GHz of bandwidth by means of very high rate sequences. In the existing proposal, the difficulty comes with the increase of the data rate, which imposes to shorten the spreading sequences. As a consequence there is an increase of the interference which results either in performance degradation or in receiver complexity increase.

Keywords: Multicode spreading, spread spectrum, ultra wideband (UWB), wireless personal area network (WPAN).

Introduction

Ultra-wideband (UWB) wireless communication is a revolutionary technology for transmitting large amounts of digital data over a wide frequency spectrum using short-pulse, low- powered radio signals. UWB commonly
Refers to a signal or system that either has a large relative bandwidth (BW) that exceeds 20% or a large absolute

Bandwidth of more than 500 MHz. A 14 February 2002 Report and Order by the Federal Communications Commission (FCC) authorizes the unlicensed use of UWB in 3.1–10.6 GHz. This is intended to provide an efficient use of scarce radio bandwidth while enabling both high data rate personal area network (PAN) wireless connectivity and longer-range, low data rate applications as well as radar and imaging systems.

UWB System

UWB Spectrum

Ultra Wide Band is defined as any system which operates with a bandwidth greater than one fourth the central frequency or larger than 500MHz. In UWB some parameters like propagation attenuation and penetration through obstacles are not constant on the whole bandwidth. This makes the channel much different from the narrow band case, mostly due to the fact that the central frequency in UWB signals cannot be considered as the carrier frequency. This increases the channel response length, and largely impacts the overall system performance. From a regulatory point of view since UWB systems overlap with existing ones, they must be limited by a spectral mask which defines the maximum power density spectrum of the transmitted UWB signal. More specifically, in the USA, the FCC limits the spectrum of UWB signals as described in the so called ‘part 15 rules’ document which is concerned with intentional radiators. The main allocated bandwidth lies between 3.1GHz and 10.5GHz, with an upper power spectral limit of −41dBm/MHz other frequency ranges are allowed in FCC part 15 but are not considered in our design.

UWB Channels

It is well known that wideband systems are impaired by inter symbol interference due to multipath. In such systems (typically a bandwidth of 5-20MHz), the receiver distinguishes some groups of paths, each group being described by an attenuation coefficient ck(t). The channel is thus identified by a finite length vector [c0 . . . cN−1]. These paths (or group of paths) correspond to spatial details which size is about few meters.

Direct Sequence Spread Spectrum

Spread Spectrum- A modulation technique that spreads a signal's power over a wide band of frequencies. The main reasons for this technique are that the signal becomes much less susceptible to electrical noise and interferes less with other radio-based systems.

Direct Sequence Spread Spectrum

Direct sequence spread spectrum combines a data signal at the sending station with a higher data rate bit sequence, which many refer to as a *chipping code* (also known as
Processing gain). A high processing gain increases the signals resistance to interference. The minimum linear processing gain that the FCC allows is 10, and most commercial products operate under 20. The IEEE 802.11 Working Group has set their minimum processing gain requirements at 11. In comparison to frequency hopping, direct sequence can achieve much higher than 2 Mbps data rates. Direct sequence spread spectrum sends a specific string of bits for each data bit sent. A chipping code is assigned to represent logic 1 and 0 data bits. As the data stream is transmitted, the corresponding code is actually sent. For example, the transmission of a data bit equal to 1 would result in the sequence 00010011100 being sent.

Characteristics of DSSS:

Highest potential data rates from individual physical layers
Smallest number of geographically separate radio cells due to a limited number of channels.
Direct sequence, has a high potential for data rates, which would be best for bandwidth intensive applications (13)
1. Combines a data signal at the sending station with a higher data rate bit sequence
2. Sends a specific string of bits for each data bit sent
3. A chipping code is assigned to represent logic 1 and 0 data bits. As the data stream is transmitted, the corresponding code is actually sent.

This system provides multiple-access, that is, many users can share the same bandwidth and each has its unique spreading sequence

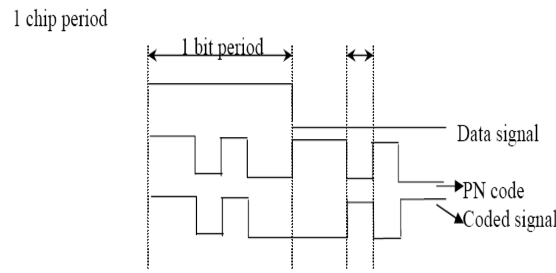

Fig No.01

4. Multiplication of each bit of base band data with the PN code will result into a spread bandwidth but the spectral power density remains the same.

Maximum Data Rate

The bandwidth which depends on the chip duration and the transmitting pulse shape.

The available data rate depends on five quantities:
1) The bandwidth which depends on the chip duration and the transmitting pulse shape. In the sequel, we consider that is given by Bw =1 /Tc
2) The code length Lc
3) The number of available codes Nc
4) The modulation order M
5) The channel capacity per information symbol C(SINR)
Where SINR is the Signal to Noise and Interference Ratio at the output of the receiver.

Given these quantities, the maximal achievable bit rate writes as:

$$R_{max} = \frac{N_c}{L_c T_c} . CM\,(SINR)$$

Where CM (SINR) is the mutual information between the emitted symbols and the received outputs for the considered modulation order. Equation involves inter-dependent quantities, since the SINR also relies on Lc and Nc. Thus, one has to look for a good trade-off between all these parameters.

Direct Sequence Multicode Transmitter Architecture

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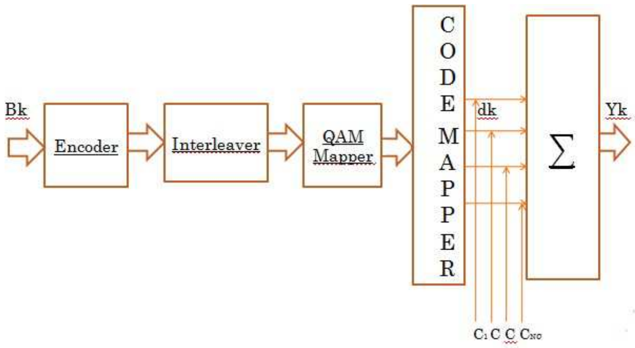

Fig No.02

Covolutional Encoder

An (n, k, m) Covolutional encoder will encode *k* bit input block in *n* bit output blocks depends up on current input blocks and *m* preceding input blocks

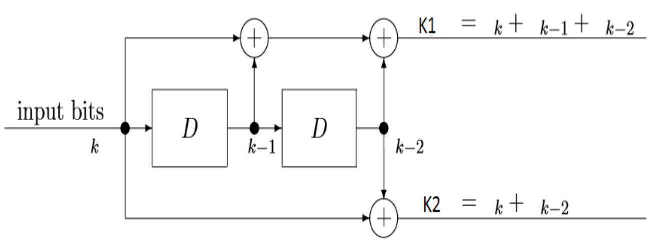

Fig No.04

Interleaver

Interleaving is a process to make a system more efficient, fast and reliable by arranging data in a noncontiguous manner.

Uses for interleaving at the system

- Storage: As hard disks and other storage devices are used to store user and system data, there is always a need to arrange the stored data in an appropriate way.
- Error Correction: Errors in data communication and memory can be corrected through interleaving.
- Multi-Dimensional Data Structures

QAM Mapping

- To increase the spectral efficiency ensured by coded QAM constellations is to map some non-coded bits, besides the coded ones on each QAM symbol.
- This approach would bring an increase coding rate for the coded configuration

Direct Sequence Linear Receivers

A general multicode linear receiver is depicted in Fig. 3. After a low noise amplifier (LNA) and a down converting stage the base-band signal is correlated by a bank of filters which delivers the received symbols.

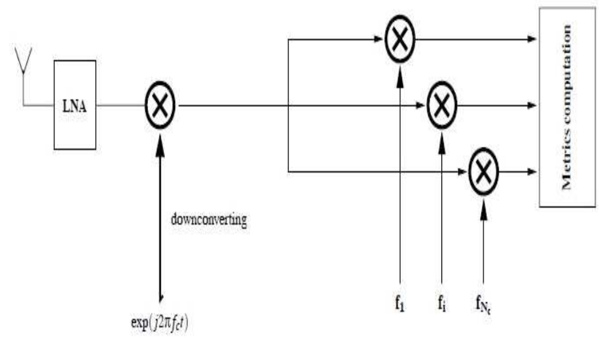

Fig No.05

2) This choice allows obtaining altogether high data rates and reduced complexity.
3) Optimization of many parameters in this context in such a way to reduce the inter symbol and the intercede interference.
4) By shortening the spreading sequences but by increasing the number of superimposed codes assigned to the same user.
5) The code length is kept long to obtain good performance of the linear receivers. Compared to existing proposals, our system design allows to enlarge the system range by quite large quantities especially for high bit rates.

Advantages

- High data rates and reduced complexity.
- 3 Optimization of many parameters to reduce the inter symbol and the intercede interference.
- By shortening the spreading sequences but by increasing the number of superimposed codes assigned to the same user.
- Good performance of the linear receivers.

Application

- Cell phone data Transfer
- Indoor applications
- PC Peripheral.
- Radio frequency sensitive environments in hospitals.

Conclusions

This contribution proposed a physical layer UWB system design based on multicode direct sequence spread spectrum allowing an efficient use of linear receivers. This choice allows obtaining altogether high data rates and reduced complexity. We showed that many parameters need to be optimized in this context in such a way to reduce the intersymbol and the intercode interference. The data rate increase is not obtained by shortening the spreading sequences but by increasing the number of superimposed codes assigned to the same user. At the same time, the code length are kept long to obtain good performance of the linear receivers. Compared to existing proposals, our system design allows to enlarge the system range by quite large quantities (up to 4) especially for high bit rates.

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