High Data Rate UWB System Design Using Multicode Approach

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***Abstract*—the world is now in a stage of major telecommunications revolutions. The need for multimedia communications and new flexible communication capabilities with high data rates and high Quality of Service (QoS) requirements become increasingly important. To fulfill these demands, this contribution provides a very high data rate UWB system design based on direct sequence spreading by multicode approach. In order to attain>=500Mbps for short range communication, two classical solutions are feasible: either use very short spreading sequences or very large bandwidth. Our approach consists in allocating multiple long codes to each user. Long codes allow coping with channel impairments while the use of multiple codes maintains very high bit rates. With such high data rates the receiver obviously has to be simple by requiring a low complexity digital processing. This system shows that the proposed strategy is compatible with simple Receivers. In fact, even if the amount of interference increases, joint usage of very long codes and simple linear receiver can result in high data rate, high performance UWB system. This assertion is substantiated through comparisons with existing UWB solutions. As to increase the data rate Firstly, 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. This method provides means of solving this problem while maintaining a scalable complexity at the receiver 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**

***Keywords*—1 UWB Spectrum,UWB,DSSS**

I. INTRODUCTION

a) 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.Ultrawide band (UWB) technology has been recognized as a feasible technology for wireless sensor networks (WSNs) applications due to its very good time-domain resolution allowing for precise location, tracking, coexistence with existing narrowband systems (due to the extremely low power spectral density) with low power and low cost on-chip implementation facility. Sensor Nodes (SN) that builds the backbone of such networks is normally micro controller based small devices. As batteries normally supply powers to these nodes that can only provide relatively small and limited processing capabilities. As a result, a number of UWB-based sensor network concepts have been developed both in the industrial and the government domain. For UWB devices, there are three independent bands i.e. the sub-gigahertz band (250–750 MHz), the low band (3.1–5 GHz), and the high band (6–10.6 GHz).

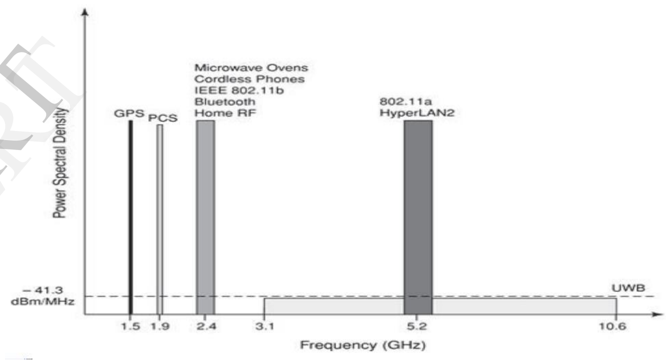

Fig no 1 UWB spectrums with some existing radio services (Source: IEEE 802.15)

Compared to narrowband systems, UWB has several advantages. UWB spreads the transmit signal over a very large bandwidth (typically 500 MHz or more). Due to the combination of wide bandwidth and low power, UWB signals have a low probability of detection facility. Additionally, the wide bandwidth gives UWB excellent immunity to interference from narrowband systems as well as from multi-path effects.

FCC regulations limit UWB devices to low average power in order to minimize interference that enables UWB coexists with narrowband systems.

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.

b) 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 is that the signal becomes much less susceptible to electrical noise and interferes less with other radio-based systems.

Direct sequence spread spectrum combines a data signal at the sending station with a higher data rate bit sequence, which many refer to asa 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

II Present Systems:

- Multi Band Orthogonal Frequency Division Modulation (MB-OFDM)
- The pulse based modulations
- Direct Sequence Spreading (DSS) has also been proposed in the UWB framework (DSUWB).

III UWB Channels:

It is well known that wideband systems are impaired byintersymbol 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 finite length vector [c0...cN−1]. These paths (or group of paths) correspond to spatial details which size is about few meters.

RAY ARRIVAK RATE IN ns^{-1}

	CM1	CM2	CM3	CM4
λ in ns-1	2.5	0.5	2.5	2.5
channel lengh in ns-1	17	13	33	60

Chart No 1

When increasing the bandwidth the receiver is able to resolve more paths. In fact, in Ultra Wide Band systems the bandwidth is so large that spatial details of few centimeters are seen on the channel at the receiver side. These channels are very long with respect to the considered symbol duration, as is evidenced by the SalehValenzuella (SV) model. TheIEEE802.15.3a task group has adopted a modified version [4] of SV model initially detailed in [5]. More precisely, a delay spread of 50ns covers only 1 sample with a 20MHz wideband systems like 802.11 however with a sampling rate of 1GHz the channel covers dozens of samples. This is the main difficulty encountered when trying to use DSUWB with very high data rates as will be shown below.

IV Motivation For Using Direct Sequence Spreading

Motivation for Spreading

The channel length seen by UWB signals makes the direct sequence spreading a serious candidate for the choice of UWB modulation. Assuming a correlation based receiver, best performance will be obtained by collecting individually the multipath rays through the spreading sequence. Thus the chip frequency must be of the same order of magnitude as the arriving process rateλ, which expresses the average number of rays per time unit.

As an example, Table I provides the values ofλas given in [4]. This gives an order of magnitude of the sampling frequency (1GHz) and of the channel length (from 17 to 60 samples). These very long channel responses also have consequences on the choice of the sequence length which must be chosen in such a way as to limit the intersymbol interference. Define the channel length as the time duration when the cluster energy falls 10dB below the first one. Corresponding channel lengths for IEEE802.15.3a task group are given in Table I. In such a situation, the use of short spreading sequences would require complex equalization schemes. Since our intent is to use very simple receivers (linear), we avoid this solution. In contrast, we choose spreading sequences longer than the channel duration. Thus, if the chip frequency is set to 1.3GHz, the maximal symbol rate would be 58Ms/s for CM1, 77Ms/s for CM2, 30Ms/s for CM3 and 16Ms/s for CM4. Obviously, this is not compatible with the target high data rates since with CM1 channel an non-coded data rate of 400Mbps requires a QAM256 modulation. We propose to recover the high data rate while keeping long spreading sequence by superimposing synchronously multiple codes. By doing so each code can be modulated with a lower order modulation.Wedenote this strategy as the 'multicode approach'. This technique has already been used with

CDMA systems in order to increase the data rate for a given user. In [6] the authors describe the basis of a multicode CDMA system and focus mainly on the code assignment. However the considered multipath channel corresponds to wideband personal communication context which is limited to few MHz of bandwidth. In [7] a code design is proposed for UWB which shows better performance than m-sequence in a UWB channel context. However this study is limited to a correlatorreceiver without forward error correction. The design which is proposed here is based on random codes, takes into account the inter-symbol interference introduced by multipath channel. As an example, an non-coded data rate of 400Mbps is achievable in CM1 context with 4 codes modulated by a QPSK constellation. This strategy relies on the assumption that increasing the code length makes the system more immune to intersymbol interference and makes the equalization easier. This is demonstrated in Section VI. A given data rate can be obtained by various combinations of modulation order, number of codes and sequence lengths.
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 codesNc

4) The modulation orderM

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 writesas:

$$\mathbf{Rmax} = \frac{\mathbf{Nc}}{\mathbf{LcTc}}\ \mathbf{.CM\ (SINR)}$$

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

The transmitter architecture is depicted in Fig. 2. The data bits are convolutionally encoded. The coded bits go through an interleaver in order to ensure that successive encoded bits meet independent channels. The encoded interleaved bits are mapped on a QAM constellation.

Fig No 2 Transmitter Architecture

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.

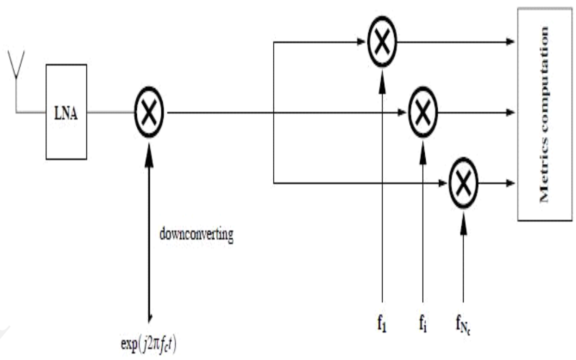

Fig No 3 Linear Receivers Architecture

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.

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