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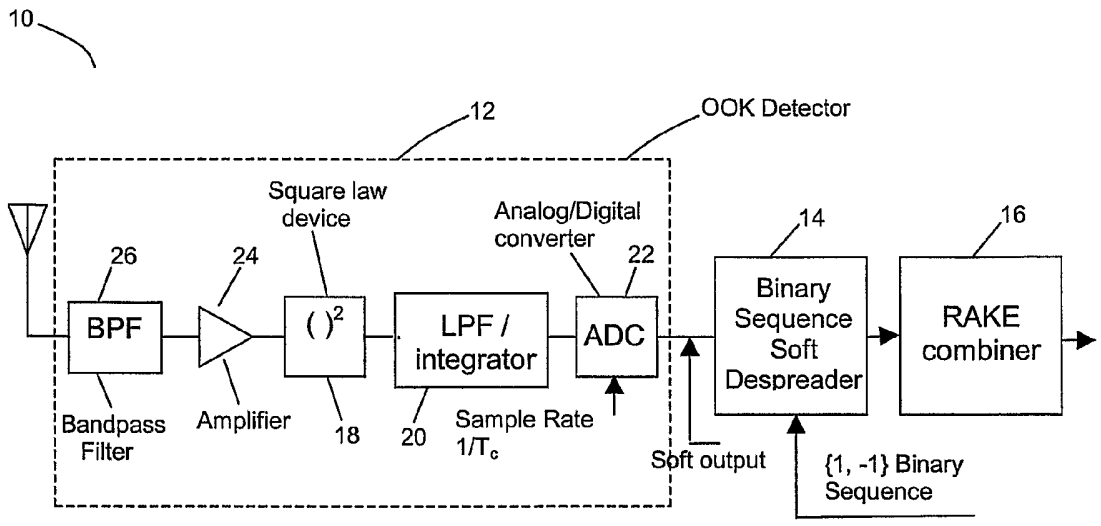
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(54) **Title:** METHOD AND SYSTEM FOR DETECTING CODE SEQUENCES IN ULTRA-WIDEBAND SYSTEMS



(57) **Abstract:** A method and a system are provided for detecting a code sequence in an ultra-wideband system. An on-off keying (OOK) detector is used for detecting a code sequence. A soft despreader is used for despreading the energy of the code sequence to provide a plurality of multipath energies. A RAKE combiner combines the plurality of multipath energies obtained from the soft despreader. The soft despreader and the RAKE combiner enable operation of an OOK receiver without using a timing recovery process block.

WO 2006/098701 A1

METHOD AND SYSTEM FOR DETECTING CODE SEQUENCES IN ULTRA-WIDEBAND SYSTEMS

Cross Reference to Related Applications:

This application claims the benefit of priority of US provisional application No. 60/662,257, filed March 16, 2005 and US provisional application No. 60/662,258, filed March 16, 2005, the contents of each being hereby incorporated by reference in its entirety for all purposes.

Field of the invention:

The invention relates, in general, to detecting code sequences in wireless communication, and in particular, to a method and a system for detecting code sequences in an ultra-wideband (UWB) system.

Background of the invention:

To detect energy in an on-off keying (OOK) system, it is conventional to integrate, sample, and set a threshold to make a decision. A timing recovery process block is required in order to find the starting point of integration. There are two types of timing recovery blocks: an analog timing recovery block and a digital timing recovery block. The analog timing recovery block includes a loop filter and a voltage control oscillator (VCO) and some other circuits that are relatively expensive to implement in the receiver. The digital timing recovery block includes a loop filter and adjustable clock blocks that are also relatively

expensive to implement. In low cost and low power consumption UWB applications, it would be advantageous if a timing recovery block did not have to be implemented.

Summary of the Invention:

A method and a system are provided for detecting a code sequence in an ultra-wideband system. An on-off keying (OOK) detector is used for detecting a code sequence. A soft despreader is used for despreading the energy of the code sequence to provide a plurality of multipath energies. A RAKE combiner combines the plurality of multipath energies obtained from the soft despreader.

Because a binary sequence soft despreader and a RAKE combiner are used, a costly timing recovery process is not required. The binary sequence soft despreader and the RAKE combiner also provide a multipath diversity gain enabling an OOK receiver to handle inter-pulse interference.

Brief Description of the Drawings:

Fig. 1 is a diagram showing examples of received code sequences;

Fig. 2 is a schematic diagram of a receiver;

Fig. 3 is a graph for illustrating integration with inter-pulse interference under a multipath scenario;

Fig. 4 is a table showing the chip sequence after integration and sampling;

Fig. 5 is three tables showing the output sequence of each rake finger after processing by the binary sequence soft despreader;

Fig. 6 is a graph for illustrating integration with inter-pulse interference under a multipath scenario without using a timing recovery block;

Fig. 7 is a table showing the chip sequence after integrating and sampling without using a timing recovery block;

Fig. 8 is three tables showing the output sequence of each rake finger after processing by the binary sequence soft despreader and without using a timing recovery block;

Fig. 9 is a block diagram showing the steps of a method for constructing a set of 2^K orthogonal N-chip ternary transmission sequences to represent a K-bit symbol;

Fig. 10 is a block diagram showing the steps of a method for constructing a set of 2^K orthogonal N-chip bipolar sequences to represent a K-bit symbol; and

Fig. 11 is a block diagram showing the steps of a method for converting a set of 2^k orthogonal N-chip ternary sequences to a set of 2^k orthogonal N-chip bipolar sequences.

Description of the Preferred Embodiments:

Fig. 2 shows an example of an on-off keying OOK receiver 10 constructed for performing a non-coherent energy detection method. The OOK receiver 10 includes an on-off keying (OOK) detector that is preferably constructed as a non-conherent on-off keying (OOK) detector 12 for detecting the energy of a received code sequence. The OOK receiver 10 also includes a soft despreader that is preferably constructed as a binary sequence soft despreader 14 using a binary sequence for despreading the soft energy value provided at the output of the OOK detector 12. Additionally, the OOK receiver 10 includes a RAKE combiner 16 for combining the multi-path energy components.

The non-coherent energy detection method explained below can be used for detecting the energy of a received code sequence. Examples of code sequences that could be received include those shown in Fig. 1. Fig. 1 shows a ternary code sequence, a binary code sequence, a ternary sequence with time hopping, and a binary sequence with time hopping.

The non-coherent OOK detector 12 uses multipath diversity to alleviate performance degradation due to the inter-pulse interference. Fig. 3 illustrates the

integration with the inter-pulse interference under a multipath scenario. In this example, the length of the code sequence is four. The multipath is assumed to diminish across three sampling periods where Tc is the sampling period. The channel impulse responses for one chip are represented as $\underline{h}_1, \underline{h}_2, \underline{h}_3$ respectively in each sampling period.

The non-coherent OOK detector 12 includes an amplifier 24, a square law device 18, an integrator 20 with a low pass filter LPF, and an analog to digital converter 22 (ADC). These blocks are conventionally used in an OOK receiver. By using the detected energy, each chip (c_1, c_2, c_3, c_4), convolves with the channel impulse responses and passes through the square law device 18 followed by the integrator 20 and the analog to digital converter 22 (ADC).

In general, a conventional OOK receiver is only able to handle received code sequences without inter-pulse interference. Fig. 3 illustrates such a case, considering inter-pulse interference due to a small duty cycle between consecutive pulses. Equivalently, the operation of a square law device, integrator, and ADC blocks can be modeled as follows:

$$r_o = \int |c*(\underline{h}_1 + \underline{h}_2 + \underline{h}_3) + \underline{n}|^2 = \int |c*(\underline{h}_1 + \underline{h}_2 + \underline{h}_3)|^2 + \eta = c*\int (|\underline{h}_1|^2 + |\underline{h}_2|^3 + |\underline{h}_3|^2) + \zeta \quad (1)$$

where:

r_o is the output of ADC, it is a binary sequence with soft value due to the square law device;

n is Additive White Gaussian Noise (AWGN);

η and ζ are corresponding terms of combined noise and inter-pulse interference; and

* denotes convolution.

This expression can be further simplified as:

$$r_o = c*(\int_0^{T_c} |\underline{h}_1|^2\, dt + \int_0^{T_c} |\underline{h}_2|^2\, dt + \int_0^{T_c} |\underline{h}_3|^2\, dt + \zeta \;= c*(e_1 + e_2 + e_3) \qquad (2)$$

where:

$$e_1 = \int_0^{T_c} |\underline{h}_1|^2\, dt,\; e_2 = \int_0^{T_c} |\underline{h}_2|^2\, dt,\; e_3 = \int_0^{T_c} |\underline{h}_3|^2\, dt;$$

e_1 is the energy captured by the integration in the first Tc period for each chip;

e_2 is the energy captured by the integration in the second Tc period for each chip; and

e_3 is the energy captured by the integration in the third Tc period for each chip.

Fig. 4 shows the chip sequence after the integration and sampling. In T_1, the output of r_o only consists of the convolution of c_1 and e_1. In T_2, the output of

r_o consists of the sum of the convolution of c_2 and e_1 and the convolution of c_1 and e_2. In T_3, the output of r_o consists of the sum of the convolution of c_3 and e_1, the convolution of c_2 and e_2, and the convolution of c_1 and e_3. In T_4, the output of r_o consists of the sum of the convolution of c_4 and e_1, the convolution of c_3 and e_2, and the convolution of c_2 and e_3. The same rule shown in Fig. 4 is followed for the subsequent cycle of the code sequence.

For a given received code sequence, for example, a ternary code sequence set having {0,+1,-1}, the received ternary code sequence set is transformed into a binary code sequence set {1,0} after passing through the square law device 18, the integrator 20, and the analog-to-digital converter 22.

Fig. 5 shows the output sequence of each RAKE finger after being processed by the binary sequence binary sequence soft despreader 14. Three RAKE fingers have been considered in this illustration. It is seen that for RAKE finger 1, the binary sequence soft despreader 14 starts from T_1. Code sequences c_1, c_2, c_3 and c_4 are subsequently multiplied with the output r_o in each Tc. For RAKE finger 2, the binary sequence soft despreader 14 starts from T_2 because there is a Tc delay. Code sequences c_1, c_2, c_3 and c_4 are subsequently multiplied with the output r_o in each Tc. Similarly, for RAKE finger 3, the binary sequence soft despreader 14 starts from T_3 because there is an additional Tc delay. Code sequences c_1, c_2, c_3 and c_4 are subsequently multiplied with the output r_o in each Tc. The darkened boxes (DB1, DB2, DB3) shown in Fig. 5

depict the binary sequence soft despreader 14 for each RAKE finger within the length of the code sequence. It is seen that for RAKE finger 1, from T_5 to T_8, due to the multipath, there is inter-pulse interference. However, because of the property of the orthogonal binary code sequence, the cross-correlation of $c_4c_1+c_1c_2+c_2c_3+c_3c_4$ and $c_3c_1+c_4c_2+c_1c_3+c_2c_4$ are very small which results in smaller inter-pulse interference. Therefore, the output of RAKE finger 1 is $e_1+\Delta e_1$, where Δe_1 is the inter-pulse interference. Similarly, for RAKE fingers 2 and 3, the output is $e_2+\Delta e_2$, $e_3+\Delta e_3$ respectively. The purpose of the RAKE combiner 16 is to combine the plurality of multipath energies collected after processing by the binary sequence soft despreader 14. In this example, the RAKE combiner 16 combines the output of these three RAKE fingers to achieve diversity gain. In an implementation, the number of RAKE fingers is chosen to achieve a trade-off between performance and complexity. The number of RAKE fingers used is less than the number of sampling periods, which is determined by the channel delay spread.

Fig. 6 illustrates an integration with inter-pulse interference under a multipath scenario without using a timing recovery block. The time index from T_1 to T_8 is for the case with timing recovery information as a reference. The time index from T_1' to T_8' is for the case without using timing recovery information. The starting point is randomly chosen. Similarly to the aforementioned equivalent method, the energy captured for each chip can be divided into e_1', e_2', e_3', and e_4', rather than into only three parts, like e_1, e_2, e_3. At the receiver, three RAKE

fingers will be used to collect energy. In each RAKE finger, the binary sequence soft despreader 14 is applied in the same manner as aforementioned. The only difference is that the inter-pulse interference due to the cross correlation among the orthogonal binary sequence will be increased. In this example, it is increased to 4. After the binary sequence soft despreader 14, each RAKE finger can collect the desired energy with a certain inter-pulse interference. The amount of inter-pulse interference is determined by the cross correlation properties. Fig. 8 shows the output sequence of each rake finger after processing by the binary sequence soft despreader 14 and without using a timing recovery block. The darkened boxes (DB1', DB2', DB3') depict the binary sequence soft despreader 14 for each RAKE finger within the length of the code sequence. Following that, the energy from three RAKE fingers can be combined together to achieve multipath diversity gain. It is found that the sum of e_1', e_2', e_3' is smaller than the sum of e_1, e_2, e_3. This implies that, in this example, the diversity gain that is obtained without using a timing recovery process block is less than when using a timing recovery block.

Including the binary sequence soft despreader 14 and the RAKE combiner 16 allows the OOK receiver 10 to work without using a timing recovery process block. As has been previously explained, such a timing recovery process block is relatively expensive to implement. Using the binary sequence soft despreader 14 and the RAKE combiner 16 provides a multipath diversity gain enabling the OOK receiver 10 to handle inter-pulse interference.

Examples of useful methods for constructing orthogonal code sequences in ultra wideband (UWB) systems will now be described. These methods may be of use when implementing the invention, however, it should be understood that conventional methods may also be used. The choice of an appropriate method for constructing orthogonal code sequences depends upon the requirements of a particular implementation.

Fig. 9 is a block diagram showing the steps of a method 100 for constructing a set of 2^K orthogonal N-chip ternary transmission sequences to represent a K-bit symbol. First, an (N-1)-chip bipolar base sequence S_0 is chosen. The (N-1)-chip bipolar base sequence S_0 is an M-sequence with a sequence sum equal to 1. The M-sequence is a Maximum-Length Shift-Register Sequence. In step 110, the bipolar base sequence S_0 is cyclically shifted by m chips to form an (N-1)-chip bipolar sequence S_1. Here, m ranges from 2 to N-2. In step 120, the bipolar base sequence S_0 is converted to form a unipolar sequence S_2 by changing -1 to 0. In step 130, the bipolar sequence S_1 and the unipolar sequence S_2 are multiplied together to form a ternary sequence T including {0,+1,-1} chips. In step 140, the ternary sequence T is cyclically shifted by $n*N/2^K$ chips to form 2^K (N-1)-chip ternary sequences T_n, where n = 1, 2, ..., 2^K. In step 150, a zero is appended to the front or to the back of each T_n to form the required 2^K N-chip ternary sequences C_n, where n = 1, 2, ..., 2^K.

In the example given below, the method 100 is implemented using the chosen bipolar base sequence S_0. The resulting bipolar sequence S_1, unipolar sequence S_2, ternary sequences T_n, and ternary sequences C_n are shown when K=2 and N=32.

S_0 = [1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -
1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1]

M = 16

S_1 = [1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 1
1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1]

S_2 = 1*(S_0==1)
= [1 1 1 0 0 0 1 1 0 1 1 1 0 1 0 1 0
0 0 0 1 0 0 1 0 1 1 0 0 1 1]

T = S_1 * S_2
= [1 -1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 1 0 0
0 0 -1 0 0 1 0 1 1 0 0 1 -1]

T_1= [1 -1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 1 0
0 0 0 -1 0 0 1 0 1 1 0 0 1 -1]

T_2= [1 0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 -1 0 -
1 1 1 0 -1 0 1 0 0 0 0 -1 0 0]

T_3= [1 0 0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 1 -1
-1 0 0 0 -1 -1 0 -1 1 1 0 -1 0]

T_4=[-1 0 -1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 1 0
1 1 0 0 1 -1 1 -1 -1 0 0 0 -1]

C_1= [0 1 -1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 1 0
0 0 0 -1 0 0 1 0 1 1 0 0 1 -1]

C_2= [0 1 0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 -1 0
-1 1 1 0 -1 0 1 0 0 0 0 -1 0 0]

C_3= [0 1 0 0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 1
-1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0]

C_4=[0 -1 0 -1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 1
0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1]

OR

C_1= [1 -1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 1 0
0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 0]

C_2= [1 0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 -1 0 -
1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 0]

C_3= [1 0 0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 1 -
1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 0]

C_4=[-1 0 -1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 1
0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 0]

C*C' =

16 0 0 0
0 16 0 0
0 0 16 0
0 0 0 16.

Fig. 10 is a block diagram showing the steps of a method 200 for constructing a set of 2^K orthogonal N-chip bipolar sequences to represent a K-bit symbol. First, an (N-1)-chip bipolar base sequence U is chosen. The (N-1)-chip bipolar base sequence U is an M-sequence with a sequence sum equal to 1.

The M-sequence is a Maximum-Length Shift-Register Sequence. In step 210, the bipolar base sequence U is cyclically shifted by $n*N/2^K$ chips to form 2^K (N-1)-chip bipolar sequences U_n, where n = 1, 2, ..., 2^K. In step 220, minus one (-1) is appended to the front or to the back of each bipolar sequence U_n to form the required 2^K N-chip bipolar sequences W_n, where n = 1, 2, ..., 2^K.

In the example given below, the method 200 is implemented using the chosen bipolar base sequence U. The resulting bipolar sequences U_n and bipolar sequences W_n are shown when K=2 and N=32.

U = [1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -
1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1]

U_1= [1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -
1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1]

U_2= [1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1
1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1]

U_3= [1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 1
1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1]

U_4= [1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1 -
1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1]

W_1= [-1 1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -
1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1]

W_2= [-1 1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -
1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1]

W_3= [-1 1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1
1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1]

W_4= [-1 1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1
1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1]

OR

W_1= [1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -
1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 -1]

W_2= [1 -1 1 1 -1 -1 1 1 -1 1 1 -1 -1 -1 1 1 -1
1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 -1]

W_3= [1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 1
1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 -1]

W_4= [1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1
-1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 -1]

W * W' =

32	0	0	0
0	32	0	0
0	0	32	0
0	0	0	32.

Fig. 11 is a block diagram showing the steps of a method 300 for converting a set of 2^K orthogonal N-chip ternary sequences C_n (where n = 1, 2, ..., 2^K) to a set of 2^K orthogonal N-chip bipolar sequences W_n (where n = 1, 2, ..., 2^K). This method 300 eliminates the need to store a set of 2^K orthogonal N-chip bipolar sequences for transmission. In step 310, all non-zero elements in the set of 2^K orthogonal N-chip ternary sequences are converted to one (1). In step 320, all zero elements in the set of 2^K orthogonal N-chip ternary sequences are converted to minus one (-1).

In the example given below, method 300 is implemented with K=2 and N=32. The ternary sequences C_n are converted to the bipolar sequences W_n.

C_1= [1 -1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 1 0
0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 0]

C_2= [1 0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 -1 0 -
1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 0]

C_3= [1 0 0 0 0 -1 0 0 1 0 1 1 0 0 1 -1 1 -
1 -1 0 0 0 -1 -1 0 -1 1 1 0 -1 0 0]

C_4=[-1 0 -1 1 1 0 -1 0 1 0 0 0 0 -1 0 0 1
0 1 1 0 0 1 -1 1 -1 -1 0 0 0 -1 0]

converted to:

W_1= [1 1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 1 -1 -
1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 -1]

W_2= [1 -1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 1 -1
1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 -1]

W_3= [1 -1 -1 -1 -1 1 -1 -1 1 -1 1 1 -1 -1 1 1 1
1 1 -1 -1 -1 1 1 -1 1 1 1 -1 1 -1 -1]

W_4= [1 -1 1 1 1 -1 1 -1 1 -1 -1 -1 -1 1 -1 -1 1
-1 1 1 -1 -1 1 1 1 1 1 -1 -1 -1 1 -1]

When implementing any of the methods 100, 200, and 300, it is desirable, but not necessary to insure the following properties: Each 2^K orthogonal N-chip ternary sequence has equal non-zeros and zeros. There is zero cross-correlation between all of the 2^K orthogonal N-chip ternary sequences. Each of the 2^K orthogonal N-chip ternary sequences has good autocorrelation properties. There is zero cross-correlation between the ternary and the corresponding binary sequence set. There is near zero cross-correlation between all sequence sets when differential detection is employed.

Methods 100, 200, and 300 can be used to help simplify UWB transmission, reduce the required memory by 50% because the need to store Bipolar sequences is eliminated, and provide a universal code sequence that is compatible with all UWB receiver types with near optimal performance.

We claim:

1. A method for detecting a code sequence in an ultra-wideband system, which comprises:

using an on-off keying detector for detecting a code sequence;

using a soft despreader for despreading an energy of the code sequence to provide a plurality of multipath energies; and

using a RAKE combiner for combining the plurality of multipath energies obtained from the soft despreader.

2. The method according to claim 1, wherein the step of detecting the code sequence includes converting the code sequence to a binary code sequence.

3. The method according to claim 1, wherein the code sequence is a ternary orthogonal code sequence.

4. The method according to claim 3, wherein the step of detecting the code sequence includes converting the code sequence to a binary code sequence.

5. The method according to claim 1, wherein the code sequence is a ternary orthogonal code sequence with time hopping.

6. The method according to claim 5, wherein the step of detecting the code sequence includes converting the code sequence to a binary code sequence.

7. The method according to claim 1, wherein the on-off keying detector is a non-coherent on-off keying receiver.

8. The method according to claim 7, wherein the step of detecting the code sequence includes converting the code sequence to a binary code sequence.

9. The method according to claim 7, wherein the non-coherent on-off keying detector includes a square law device, an integrator, and an analog-to-digital converter.

10. The method according to claim 9, wherein the step of detecting the code sequence includes converting the code sequence to a binary code sequence.

11. The method according to claim 1, wherein the soft despreader is a binary sequence soft despreader.

12. A system for detecting a code sequence in an ultra-wideband system, which comprises:

an on-off keying detector for detecting a code sequence;

a soft despreader for despreading an energy of the code sequence to provide a plurality of multipath energies; and

a RAKE combiner for combining the plurality of multipath energies obtained from the soft despreader.

13. The system according to claim 12, wherein the code sequence is a ternary orthogonal code sequence.

14. The system according to claim 12, wherein the code sequence is a ternary orthogonal code sequence with time hopping.

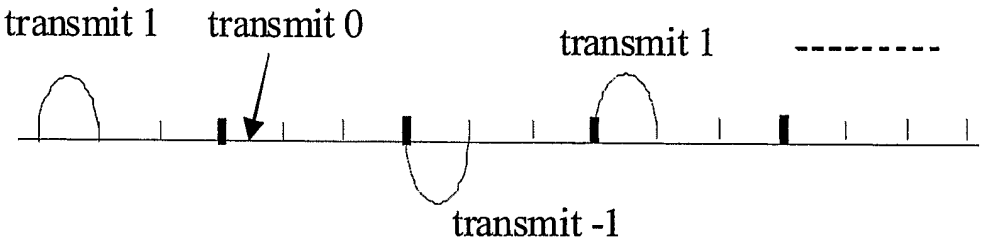
15. The system according to claim 12, wherein the on-off keying detector is a non-coherent on-off keying detector.

16. The system according to claim 15, wherein the non-coherent on-off keying detector includes a square law device, an integrator, and an analog-to-digital converter.

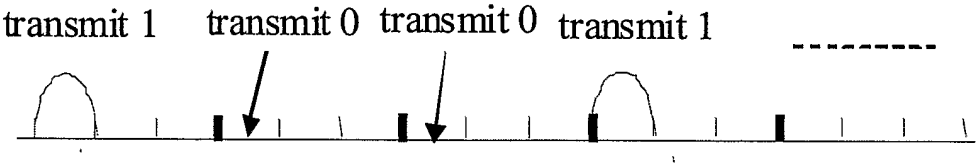
17. The system according to claim 12, wherein the on-off keying detector converts the code sequence to a binary code sequence.

18. The system according to claim 12, wherein the soft despreader is a binary sequence soft despreader.

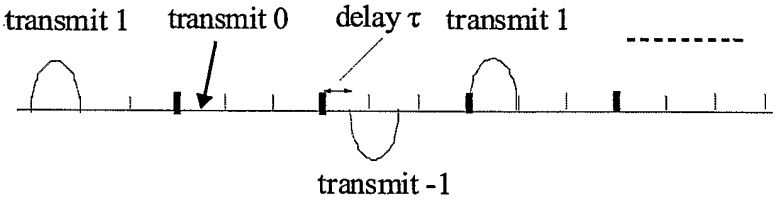
Ternary sequence



Binary sequence



Ternary sequence with time hopping



Binary sequence with time hopping

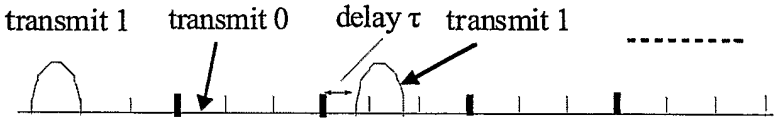


Figure 1

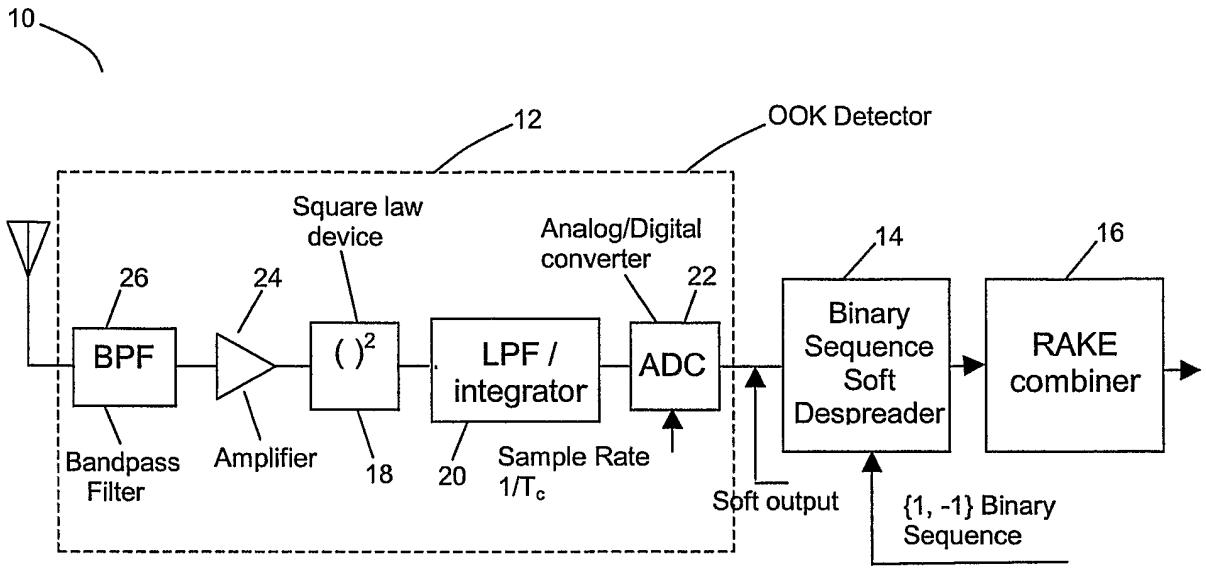


Figure 2

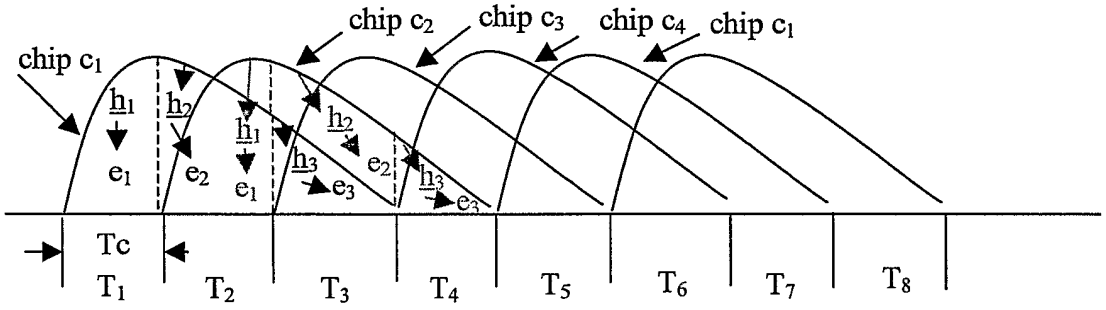


Figure 3

		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
$\sum$	e_1*	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2
	e_2*		c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1
	e_3*			c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4

Figure 4

RAKE finger 1

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
E_{1*}	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4
E_{2*}		c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3	c_3c_4
E_{3*}			c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4

$e_1+\Delta e_1$ DB1

RAKE finger 2

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
e_{1*}	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3
e_{2*}		c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3
e_{3*}			c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3

$e_2+\Delta e_2$ DB2

RAKE finger 3

	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
e_{1*}	c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2
e_{2*}		c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2
e_{3*}			c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2

$e_3+\Delta e_3$ DB3

Figure 5

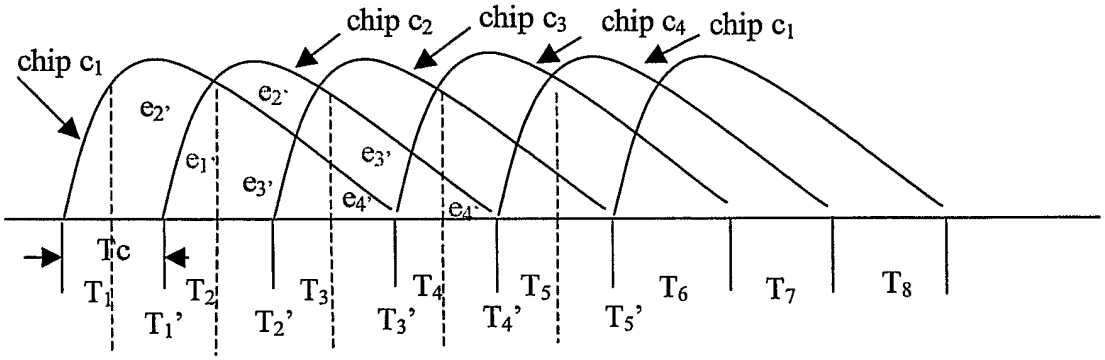


Figure 6

	T_1'	T_2'	T_3'	T_4'	T_5'	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
$e_1'*$	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3
$e_2'*$	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2
$e_3'*$		c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1
$e_4'*$			c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4	c_1	c_2	c_3	c_4

Figure 7

RAKE finger 1

	T_1'	T_2'	T_3'	T_4'	T_5'	T_6'	T_7'	T_8'	T_9'	T_{10}'
$e_1'*$	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3
$e_2'*$	c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3
$e_3'*$		c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3
$e_4'*$			c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3

DB1'

$e_1'+\Delta e_1'$

RAKE finger 2

	T_1'	T_2'	T_3'	T_4'	T_5'	T_6'	T_7'	T_8'	T_9'	T_{10}'
$e_1'*$	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2
$e_2'*$	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_1
$e_3'*$		c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2	c_2c_3	c_3c_4	c_4c_1	c_1c_2
$e_4'*$			c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2

DB2'

$e_2'+\Delta e_2'$

RAKE finger 3

	T_1'	T_2'	T_3'	T_4'	T_5'	T_6'	T_7'	T_8'	T_9'	T_{10}'
$e_1'*$	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1	c_4c_2	c_1c_3	c_2c_4	c_3c_1
$e_2'*$	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1
$e_3'*$		c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1	c_2c_2	c_3c_3	c_4c_4	c_1c_1
$e_4'*$			c_1c_4	c_2c_1	c_3c_2	c_4c_3	c_1c_4	c_2c_1	c_3c_2	c_4c_3

DB3'

$e_3'+\Delta e_3'$

Figure 8

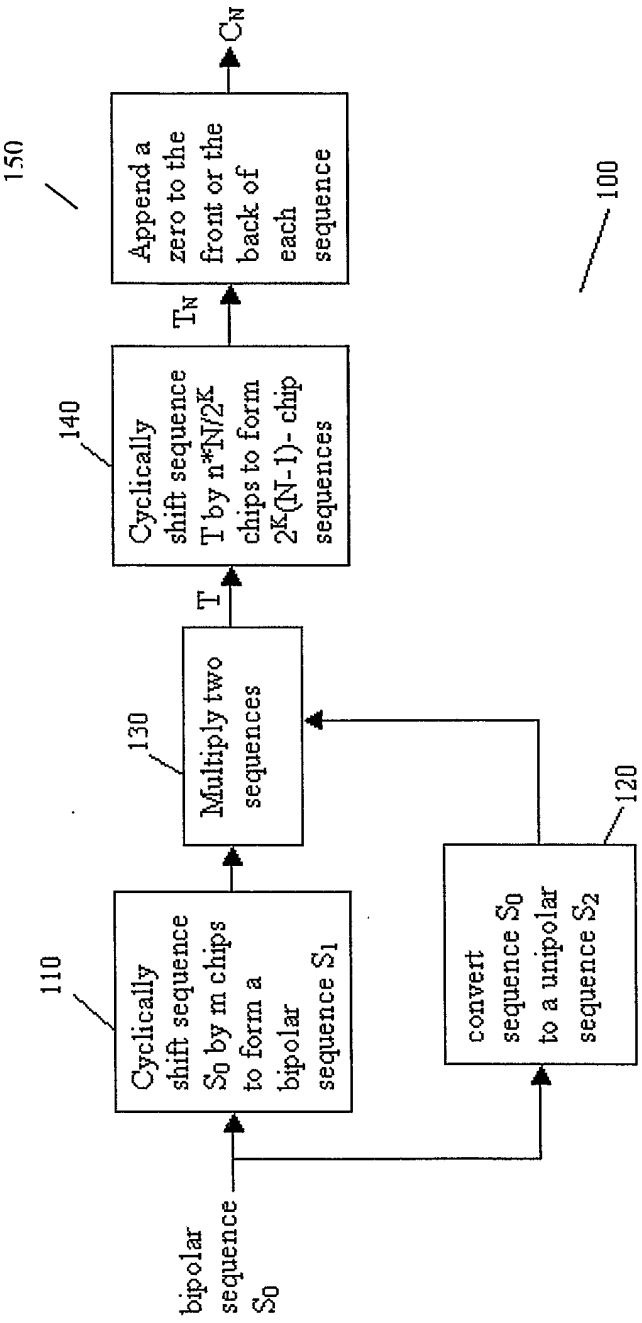

bipolar sequence S_0
110
Cyclically shift sequence S_0 by m chips to form a bipolar sequence S_1
120
convert sequence S_0 to a unipolar sequence S_2
130
Multiply two sequences
T
140
Cyclically shift sequence T by n*N/2K chips to form $2^K(N-1)$- chip sequences
T_N
150
Append a zero to the front or the back of each sequence
C_N
100

Figure 9

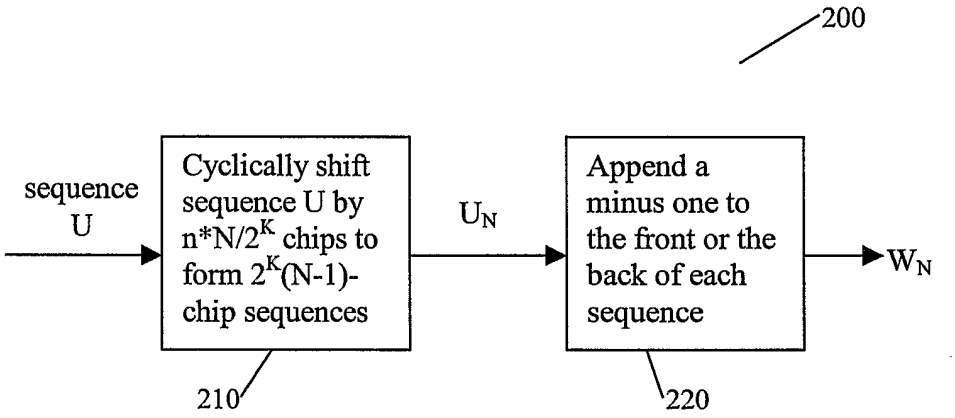


Figure 10

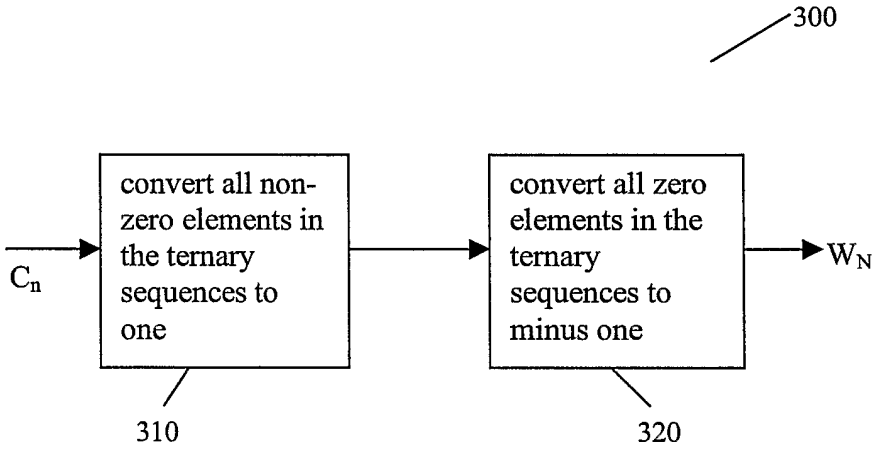


Figure 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2006/000056

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04B 1/10 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT: Keywords: (UWB, OOK, RAKE, receiver, soft despread, soft decode, soft decision and like terms); Google: Keywords: (UWB, OOK, RAKE, receiver, soft decision and like terms)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CHIN et al. Proposed Code Sequences for IEEE 802.15a Alt-PHY. IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs), 16 January 2005 [retrieved on 7 April 2006]. Retrieved from the Internet: <URL: http://www.ieee802.org/15/pub/05/15-05-0032-01-004a-proposed-code-sequences-modulation-coding-ieee-802-15-4a-alt-phy.ppt>. See in particular slides 3 – 5 and 12.	1 – 18
Y	YANG et al. Ultra-Wideband Communications. IEEE Signal Processing Magazine, vol. 21, no. 6, pp. 26 – 54, November 2004. See in particular pp. 33, 36 – 37 and 40 – 44.	1 – 18
Y	PAQUELET et al. RF front-end considerations for SDR ultra-wideband communications systems. RF Design Magazine, pp. 44 – 51, July 2004. See in particular pp. 44, 48 and 50.	1 – 18

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 April 2006	24 APR 2006
Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	**DALE E. SIVER** Telephone No : (02) 6283 2196

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2006/000056

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	QIU et al. Ultra-Wideband for Multiple Access Communications. IEEE Communications Magazine, vol. 43, no. 2, pp. 80 – 87, February 2005. See in particular pp. 80 – 81.	1 – 18
A	CHIN et al. How energy Detector handles Inter-Pulse Interference? IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs), 12 May 2005 [retrieved on 7 April 2006]. Retrieved from the Internet: <URL: http://www.ieee802.org/15/pub/05/15-05-0257-01-004a-how-energy-detector-handles-inter-pulse-interference.ppt>. See entire document.	
A	YANG et al. Noncoherent ultra-wideband radios. IEEE Military Communications Conference, 2004 (MILCOM 2004), vol. 2, pp. 786 – 791, 31 October – 3 November 2004. See in particular pp 786 – 787.	
A	AGEE et al. Soft Synchronization of Direct Sequence Spread-Spectrum Signals. IEEE Transactions on Communications, vol. 44, no. 11, pp. 1527 – 1535, November 1996. See entire document.	
A	US 2002/0097790 A1 (DRESS, JR. et al.) 25 July 2002. See entire document.	
A	HEYDARI. A Study of Low-Power Ultra Wideband Radio Transceiver Architectures. IEEE Wireless Communications and Networking Conference (WCNC), vol. 2, pp. 758 – 763, 13 – 17 March 2005. See entire document.	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2006/000056

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member					
US 2002097790	AU	71277/00	CA	2385417	CA	2498526
	EP	1228613	EP	1505785	PL	356992
	US	6603818	US	6606350	US	6621878
	US	6625229	US	2002080889	US	2002146080
	WO	0122672				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX