Preamble Detector and Synchronization in the TDD mode for BWA System

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Abstract: On the TDD system, the uplink and downlink transmission share the same frequency but are seperated in time. In this paper we just consider the uplink transmission.

The BWA system in this paper should be accepted the adaptive modulation. Each uplink burst shall begin with an uplink preamble. The recetption of an uplink burst is the most challenging from a synchronization perspective. The burst detection, power estimation, symbol synchronization and carrier synchronization should be obtained from the preamble. It will be shown in this paper, how can get a burst detection by preambles and extract the synchronization parameter from preamble.

1. Introduction

BWA System Based on IEEE 802.16 supports the three method of transmission, the Framed FDD, Unframed FDD and TDD.

In the TDD system, the uplink and downlink transmission share the same frequency but are separated in time. A TDD frame has a fixed duration and contains one downlink and one uplink subframe, the TDD framing is adaptive in that the link capacity allocated to the downlink versus the uplink may vary. In order to minimize the complexity of the radio-frequency elements at the subscriber station(SS) the uplink and downlink carrier frequencies shall reference each other and there are also exists an initial ranging processor frequency and power calibration. After the initial frequency has been calibrated, periodic measurements of the frequency offset value at the Base Station(BS) shall be made by the physical layer and sent to the SS via a MAC message.

The subscriber transmitter derives its carrier frequency from the same local oscillator, So there will be no frequency offsets to resolve from the preamble and the detector gets simplified. In the uplink base station receiver has in addition to extract the symbol synchronization from the preamble because there is no continuous uplink waveform to lock. In this point, The detection probability of correct start point of preamble is very important appraised parameters.

In this paper, A new preamble detector structure is proposed, Including the frame indication and detection of correct frame start point in the uplink transmission. The synchronization parameters can be extracted from cross correlator of preamble detector.

All synchronization parameters considered in this paper can use in the system accepting 2 over sampled signal.

2. Preamble Detector

Synchronization is the process where the receiver clocks are adjusted according to the transmitter clocks. When communicating in burst mode rapid synchronization is needed, Preambles are used to achieve fast synchronization for the burst.. Here it is assumed that the preamble is mainly used for synchronization purpose and not for channel equalization purposes. It is also assumed that the receiver uses coherent detection while the preamble processing is noncoherent. With coherence we mean that the carrier phase is known and also used in the detection process.

It is also assumed that the receivers is "memory less" in the sense that symbols are demodulated as they are received as opposed to systems where the signal is stored in memory and is afterwards processed.

Memoryless system requires a high detection probability. Therefore the new structure to detect the preamble is proposed.

The preamble is a known pattern that is sent at the start of the preamble for the synchronization. If we detect the correct point of the preamble, we can use the following types of synchronization parameters estimated by the preamble.

The most obvious use of the preamble is the detection of a burst. If there is no knowledge of the time of arrival, the preamble should be long enough so that the probability that the preamble pattern occurs in the data segment of a burst is sufficiently small. Often there is some knowledge of the time of arrival so the preamble hunting can be confined to a window. The missed preamble probability and the false alarm probability are the basic figures of merit for the preamble detector. The detection of the preamble will trigger the demodulation of the burst.

The IEEE 802.16 Standard, It accepts 32 symbol CAZAC preamble, which has good auto correlation properties and helps to get an exact start point of burst indication. Hence it must be designed to work with a lower S/N than the other payload signal in the same burst.

The detection of the preamble is typically done with a correlator or a matched filter sliding through the signal. This operation takes place in the baseband, so it actually works with complex signals. The complex correlation works according to the basic definition of a correlator

$$z = \sum r \cdot c^{*} \qquad (1)$$

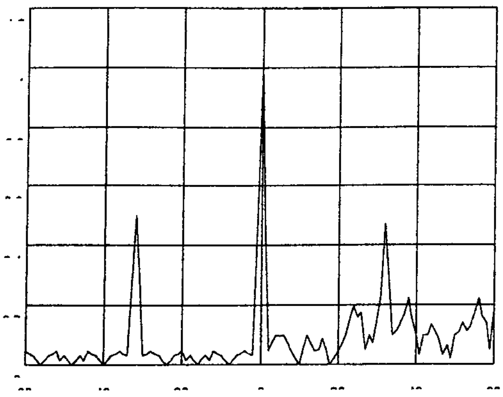

Figure 1. The output of cross correlator

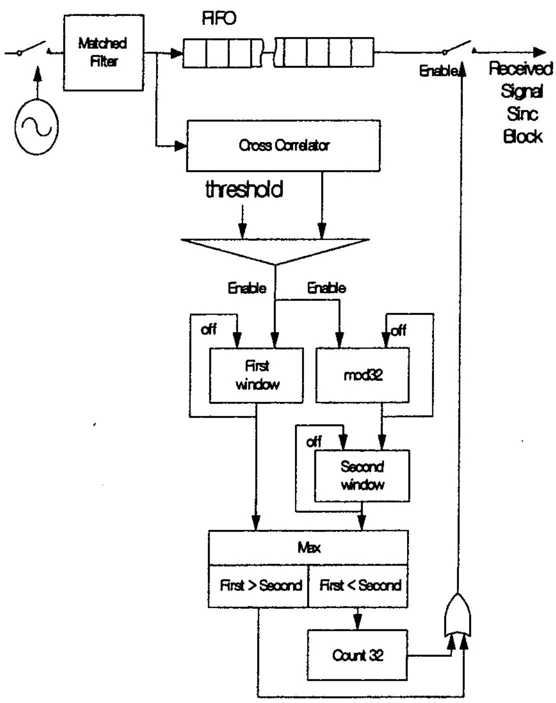

Figure 2. Structure of Preamble Detector

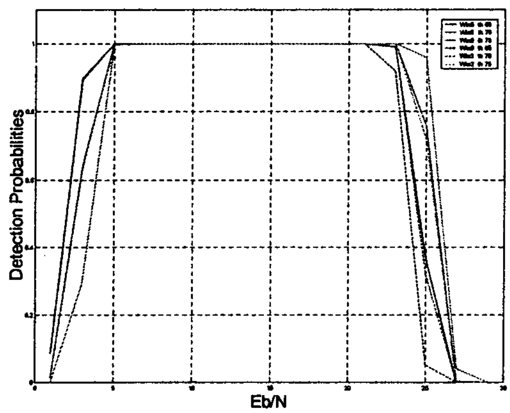

Figure 3. Detection Probabilities of preamble Detector

$$r = r_x + ir_y$$
$$c = c_x + ic_y \qquad (2)$$

r is the incoming signal where r_x is real part, in the I channel, and r_y is imaginary part, in the Q channel. c_x and c_y are the real respective imaginary part of the preamble pattern. * denotes the complex conjugate. Because the c_x and c_y are equal to +-1 it will simplify the detector as no multiplication is actually needed. Summation is performed over N symbols, where N is the length of the preamble

$$z = \sum_N (r_x + ir_y) \cdot (c_x - ic_y) \qquad (3)$$

$$z = \sum_N (r_x c_x + r_y c_y) + i \sum_N (r_y c_x - r_x c_y) \qquad (4)$$

the power of the preamble is then

$$P = (\sum_N (r_x c_x + r_y c_y))^2 + (\sum_N (r_y c_x - r_x c_y))^2 \qquad (5)$$

The structure of preamble detector is figure 2 and the detection probabilities per Eb/N followed by threshold and window size.

P should exceed a threshold value for detection of an incoming burst. Figure 1 shows the output of correlator. Note that there are 3 peak points in the figure 1.

To use the correlator output as a control signal for preamble detector, we propose a new structure of preamble detector, which can develop the probability of preamble detection in the head of burst signal.

Proposed preamble detector works as following way. In the first step, The cross correlator work on signals accepted from outside including the noise. Then compare with a predefined threhold which is smaller than the first peak point of the figure 1. If the control signal generated from comparison block, the first window saves the output of the correlator during the predefined interval and the first counter operates for 32 sampling times. Then save the output of correlator for the second window duration. During the test of preamble detection, the output of correlators, Each I and Q phase data has to be gone into the queue..In the second step. Maximum value of the first window is compared with the one of second. If the maximum value in the first window is greater than the second, The data stored in the queue can get into the demodulator block in the BS receiver. The other case, data stored in queues can be getting into the demodulator block after counting 32 sampling time.

Figure 3 shows the probabilities of preamble detector by threshold level and window size.

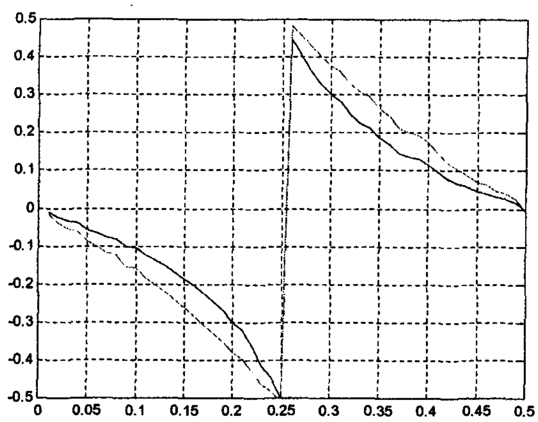

Figure 4. Estimated Timing Error

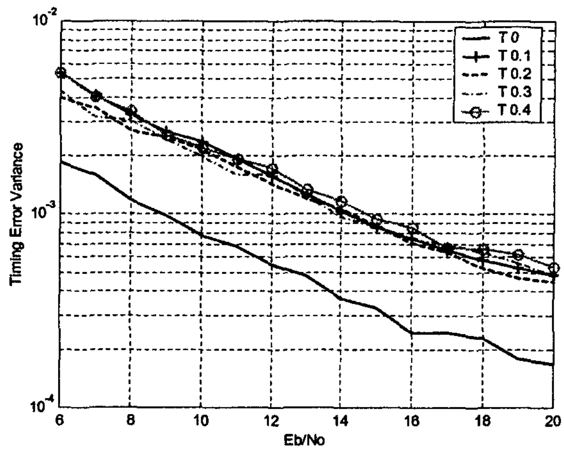

Figure 5. Error Variance of Timing Estimator

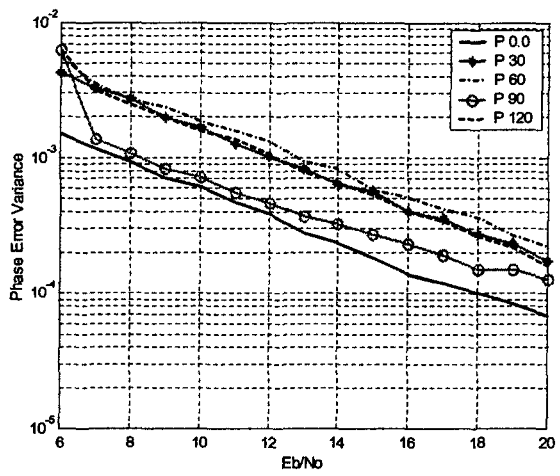

Figure 6. Error Variance of Phase Error

3. Synchronization Parameters

In this paper, It is assumed that the preamble is mainly used for synchronization purpose, not for channel equalization purposes and the preamble was detected correctly. It is also assumed that the receiver uses coherent detection while the preamble processing is non coherent. With coherence we mean that the carrier phase is known and also used in the detection process.
IEEE 802.16 standard accepts the adaptive modulation so it's payload of frame can be different with preamble. It means that the synchronization parameters should be extracted from preambles

3.1 Symbol Clock estimation

Symbol clock timing can be extracted from the preamble detector using the output of correlator. We use the output of correlation results in the Figure 1. Differential value of the largest peak point is zero and can be applied to following polynomials.

Assume the fractional interval of sampling time can be described in the form of the second order polynomial as follows.

$$|\mu(\varepsilon)| = b_2 t^2 + b_1 t + b_0 \tag{6}$$

$$t_{peak} = -\frac{b_1}{2b_2} = \frac{(x_0 - x_2)T_s}{2x_0 - 4x_1 + 2x_2} \tag{7}$$

The differential value of follow polynomial means the timing error values. the following equation is compatible on the 4 over sampling per symbol. But we should get Synchronization parameters from 2 over sampled signals. So we use arctan table to compensate the estimated error variance from the non linear estimated result, Figure 4 Shows the linearity of new method of timing estimator and Figure 5 Shows the estimation reselts of linearlized Timing Estiamtor.

3.2 Carrier phase estimate

Every coherent receiver knows and uses the carrier phase in the demodulation process. Because a coherent receiver has

a smaller bit error rate than a non-coherent receiver. The preamble detector shall give an initial estimate of the carrier phase, which is then updated by the receiver control loop. The phase can be estimated with the following expression.

Figure 6 shows the estimation results of Phase estiamtor.

$$\Phi = \arctan\left(\frac{\mathrm{Im}\sum_{N} r \cdot x^{*}}{\mathrm{Re}\sum_{N} r \cdot x^{*}}\right) \tag{8}$$

4. Conclusion

The TDMA transmission in the TDD mode needs to treat the fast and short burst framed signal. It means that the BS has to do a real time calculation of the received signal without large memory blocks. Hence indication of the frame and detection of the start point of burst signal are very important issue of burst signal processing.

In this paper, we propose a new structure of preamble detector to develop the detection probability, get synchronization parameters in low S/N and show the results of simulation.

As a results of simulation, We can use proposed algirithms for treat the uplink signal that was 2 over sampled per symbol.

Reference

[1] yimin Jiang "Data-Aided ML Parameter Estimators for PSK burst Modems and their systolic VLSI implementation" *Global Telecommunications conference*

[2] yimin Jiang "VLSI implemented ML joint Carrier phase and timing offsets estimator for QPSK/OQPSK burst modems", *IEEE 1999*