Quest Journals
Journal of Software Engineering and Simulation
Volume 3 ~ Issue 6 (2017) pp: 06-11
ISSN(Online) :2321-3795 ISSN (Print):2321-3809
www.questjournals.org

Research Paper

Frame Synchronization in Digital Communication Systems

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Received 09 Feb. 2017; **A**ccepted 25 Feb. © The author(s) 2017. **P**ublished with open access at **www.questjournals.org**

Abstract: *This paper introduces the problem of frame synchronization in digital communication receiver and evaluates the performance of using different sequences for frame synchronization such as Barker, Neuman-Hofman and PN sequences. In this work we use a correlation rule based method where the receiver, after recovering phase value, the given input values are correlated with a sync pattern (marker) and the frame synchronization is obtained by examining the correlation values. Computer simulation is made by using MATLAB-SIMULINK program and the results show that the correlation rule based method has acceptable performance and implementation simplicity.*

Keywords: *Frame Synchronization, Barker Sequence, Neuman-Hofman Sequence, PN Sequence, Digital Communication System.*

I. INTRODUCTION

In digital communication systems data is not send as a simple stream of bits or bytes but in terms of frames or packets. So, the receiver must be able to recognize the start of the frame by process called frame synchronization. Generally, there are three levels of synchronization in a complete communication system: carrier synchronization, symbol synchronization, frame synchronization. Carrier synchronization refers to the process of generating a reference carrier with frequency and phase that is close to frequency and phase of a received carrier. Symbol carrier refers to the process of deriving timing signals at the receiver which indicate where, in time, the transmitted symbols are located. Once symbol synchronization is accomplished, the next synchronization level is frame synchronization. It is easily seen that achievement of frame synchronization automatically implies symbol synchronization, but the converse is not true.

Frame synchronization is the method used by receiver to locate the time position of the start of the frame [1], i.e., the receiver needs a frame synchronization process to know where each frame of the transmitted frames starts in order to demodulate the transmitted data. This process is achieved in several steps. First, the transmitter inserts a fixed length symbol pattern called a marker into the beginning of each frame to form a marker and frame pair, which is known as a packet. Packets are then converted from symbols into a waveform and transmitted through the channel. The receiver detects the arrival of packets by searching for the marker, then removes the markers from the data.

Various method for locating marker in data for binary Communication system over Additive White Gaussian Noise (AWGN) channels was explained in [2] for the case of periodically embedded marker (i.e., frames having all the same length) and binary signaling with coherent demodulation, assuming perfect carrier frequency and phase acquisition has been achieved prior to frame synchronization . The design of a marker in the presence of back ground noise is discussed in the Scholtz [5]. Massey introduces optimum method [2] for finding location of a marker which give a 3dB advantage over the other correlation methods. This rule is complicated than other correlation methods. Extensions to multilevel modulation, frequency offset, non coherent modulations and code-aided frame synchronization techniques are provided in [3, 4, 6, 14, 18].

This paper is organized as follows. The system description of the frame synchronizer is presented in section 2. In section 3, the simulation model is presented, while the simulation results are presented and analyzed in section4. Finally, concluding remarks is presented in section5.

II. SYSTEM DESCRIPTION

Figure 1 shows the general frame structure for digital data communication system. Here the marker is periodically inserted by the transmitter in each start of each frame of data. At the receiver there is a correlation between the received frame and stored marker pattern and frame synchronization is obtained by examining the correlation values.

It is better to choose a marker pattern used in frame synchronization with good autocorrelation properties. Usually in the techniques of frame synchronization, special sequences such as Barker sequences [6], are used for frame synchronization in digital communication systems. They are applied in Massey [2], Liu and Tan [3] and Moon [6]. In these papers, 7- symbol Barker sequence (-1,-1,-1,1,1,-1,1), 13-symbol Barker sequence (-1,-1,-1,-1,-1,1,1,-1,-1,1, -1,1,-1) and 13- symbol Neuman-Hofman sequence (1,1,1,1,1,1,-1,-1,1,1,-1,1,-1) are used as a marker pattern in frame structures.

In this paper, we will use 7- symbol Barker sequence (BK7), 13- symbol Barker sequence (BK13) and 13- symbol Neuman-Hofman (NH13) sequence as in [2, 3, 5], and also introduce 11- symbol Barker sequence (BK11) and a 15- symbol PN (PN15) sequences as a marker sequence for frame synchronization. The 11-symbol Barker code sequence and the 15- symbol PN sequence also have good autocorrelation properties. These two sequences are introduced in order to enhance the performance of frame synchronizer system with more marker sequences and find out in which case the performance of frame synchronizer works best. The system is simulated by using MATLAB-SIMULINK program.

III. SIMULATION MODEL OF FRAME SYNCHRONIZER

In the Simulink model the system used a random binary sequence to present the data then the marker is injected into the beginning of each frame by concatenating the output of the marker sequence and the output of the random binary sequence to form a marker and frame pair, which is known as a packet. The packets are modulated using BPSK modulation scheme and this waveform is transmitted through the channel. In the receiver, the arrival of packets is detected by searching for the marker, then the receiver removes the marker from the data stream and bi error rate is calculated. Figure 2 shows the block diagram of frame synchronizer scheme considered in this paper.

As shown in Figure 2 the system consists mainly of the following parts: transmitter, channel, and receiver:

1- Transmitter side,
2- Channel,
3- Receiver side.

And we will discuss the above parts in the following.

(A) Transmitter side:

The transmitter side consists of these main parts Marker Code Generator, Bernouli Binary Generator, Matrix Concatenate and BPSK modulator. The Marker Code Generator is (Barker code with length 13, or 11, or 7) or (Neuman-Hofman code with length 13) or (PN code with length 15). Since Marker Code Generator output is 1,-1 and the Bernoulli Binary Generator output is either 1 or 0. In order to attach the marker code to the frame, we need to change its format using the Bipolar to Unipolar converter block. The binary data used in this system are produced using Bernoulli expression, this data represents the actual data that will be transmitted. The binary value are generated according a probability p. The zero value has a probability of p and the one value has a probability of (1-p). In this system the value of the probability p will be (0.5) which means that the 0´s and 1´s having the same generation probability. The sample time of the output is (1/200) sec and sample per frame is 200 i.e., if we use Barker code with length 13 as a marker for output frame the length of the frame after concatenation is equal to 213 symbol where 13symbol for marker and 200 symbol data. For different lengths of Barker code (7,11,13) the frame length after concatenation will be (207,211, and 213). The output packets are modulated using BPSK modulation scheme and sent to a channel.

(B) Channel:

As shown in Figure 2 the channel consists of two blocks, the delay block and AWGN block. The delay block is used to simulate real channel, we put a delay and watch if the receiver can compute this delay or not. When the receiver determine this delay, it can know where the start of the frame, i.e., where should be the starting point of decoding. The channel type used in this system is the Additive White Gaussian Noise (AWGN) channel added noise to the input signal in order to represents the real transmission environment. The channel mode used in this system is the signal to noise ratio Eb/No and a sample period of (1/frame length) sec.

(C) Receiver Side:

As shown in Figure 2, the output of the AWGN channel is applied to the receiver side. At receiver, First demodulated data is converted from unipolar to Bipolar using unipolar to Bipolar converter to be the same as a stored version of a marker sequence stored, then the received data and the stored version of marker code is fed to Align signal subsystem. The Align signal subsystem consists of two main subsystems Enabled Compute

Delay subsystem and Consecutive Delay Computation subsystem. In Enabled Compute Delay subsystem there is a correlation process to find out the value and index of the peak of the correlation of received data and marker code. The index of the maximum value represents the position of the start of frame, it is subtracted from frame length value and then make a modulo operation between the frame length and this index. Figure 3 & Figure 4 shows Enabled Compute Delay subsystem and Consecutive Delay Computation subsystem.

As shown in Figure 3 & Figure 4, the function of Enabled Compute delay subsystem is calculating the delay of the channel, while the function of the Consecutive Delay Computation subsystem is checking whether the calculated delay remains the same for several iterations. If it is, the Enabled Delay Computation subsystem is disabled. This is because once the same delay has been estimated for many iterations, then we can confident that the estimate is correct and need not to be recalculated.

IV. RESULTS

In simulation results, we compare all the above marker sequences (Barker code with different length (7,11,13), Neuman-Hofman code 13 and PN code 15) by measuring the bit error rate of the communication system which using one of the above marker sequence. Figure 5 shows the comparison between all these marker sequences at frame length 200 symbol. We find that three of these markers (Barker code 13, Barker code 11, and Neuman-Hofman 13) have the same performance, while the other two marker sequences (Barker code 7 and PN 15) have performance different. As expected we get that the performance of Barker code 7 is the worst because it saturates nearly at value $2.6*10^{-4}$ at E_b/N_o=10dB. We mean by word saturation that the performance doesn't enhance when increasing E_b/N_o, i.e., bit error rate value reach constant value. As shown in Figure 5, we get that the performance of PN 15 is better than the performance of Barker 7 because it saturates at value about $8*10^{-6}$ at E_b/N_o = 11dB.

To differentiate between the other three marker sequences (Barker 13, Barker 11 and Neuman-Hofman 13) we increase frame length to 1000 symbol instead of 200 symbol. As shown in Figure 6, Barker 13 is the best performance because when E_b/N_o increased, bit error rate enhanced. We get that Neuman-Hofman 13 saturates at $4*10^{-5}$ while Barker 11 saturates at $3*10^{-6}$. At E_b/N_o less than or equal 8 dB the performance of all these three markers are equal.

V. CONCLUSION

This paper presented a proposed algorithm for the correlation rule based frame synchronizer technique developed by MATLAB and Simulink. It developed and tested with AWGN channels. We compared the performance of using different sequences for frame synchronization such as Barker, Neuman-Hofman, and PN sequences. We concluded that if the frame length is equal to 200 symbol and the E_b/N_o is less than or equal to 7dB Barker 7 is the optimum because the performance of all sequences are the same but the throughput of Barker 7 is the best.

If the frame length =1000 symbol and E_b/N_o is more than 10 dB the best one is Barker 13. In addition, our technique leads to simpler analysis and is somewhat simpler to implement.

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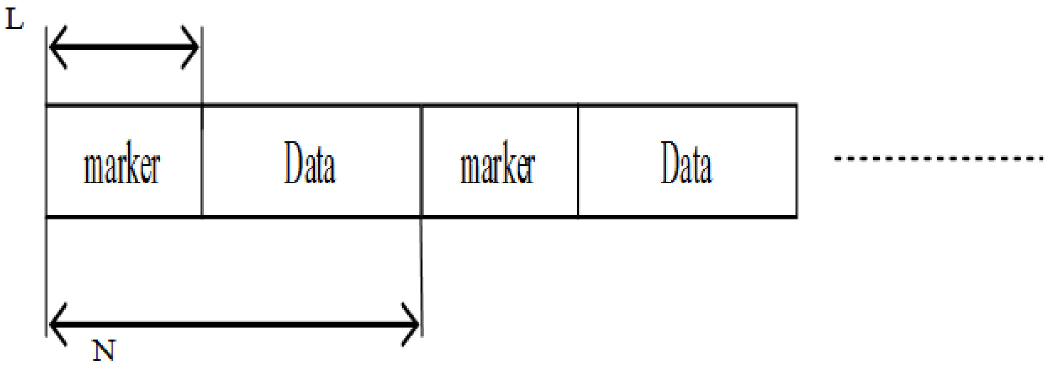


Fig 1 Frame structure of continuous data

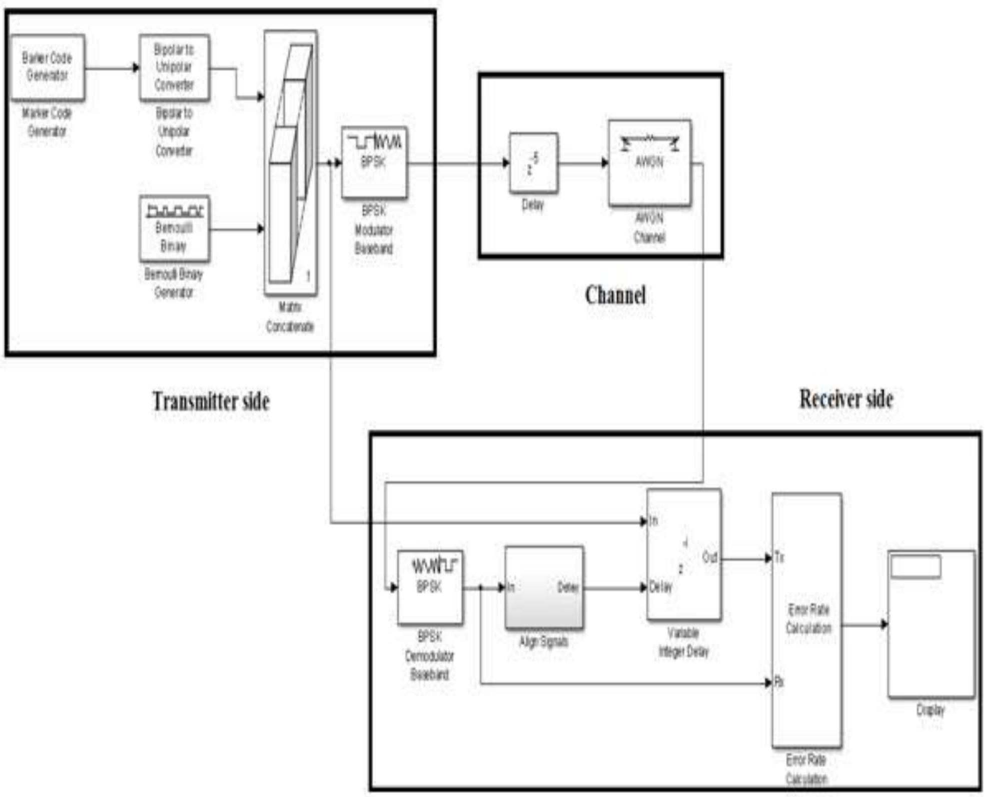


Fig. 2 Frame Synchronizer simulation system design

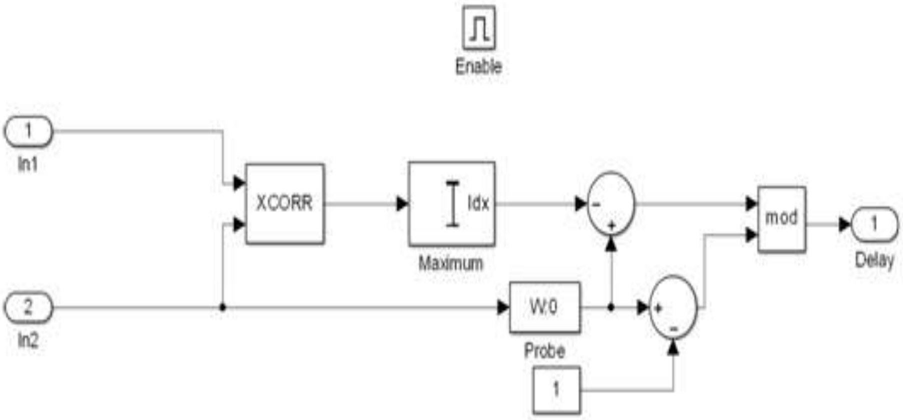


Fig. 3 Enabled Delay Computation subsystem

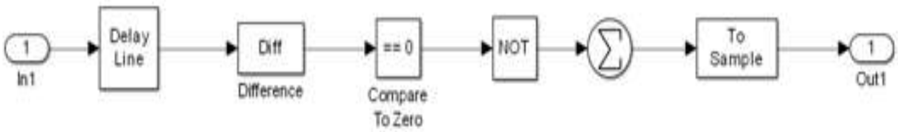
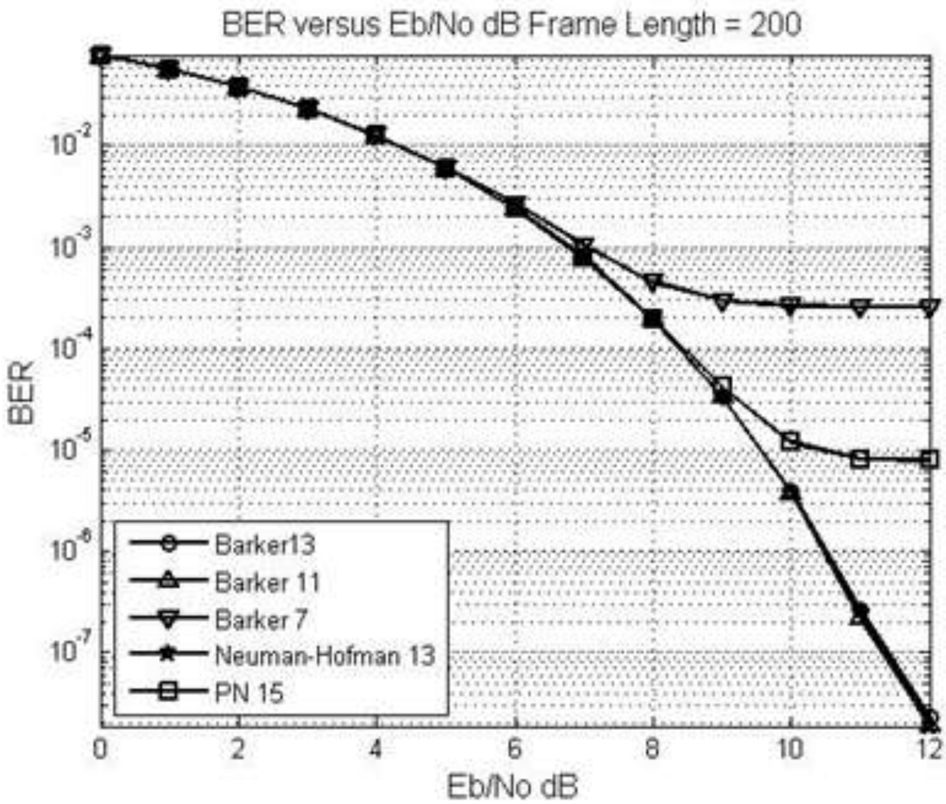


Fig. 4 Consecutive Delay Computation subsystem



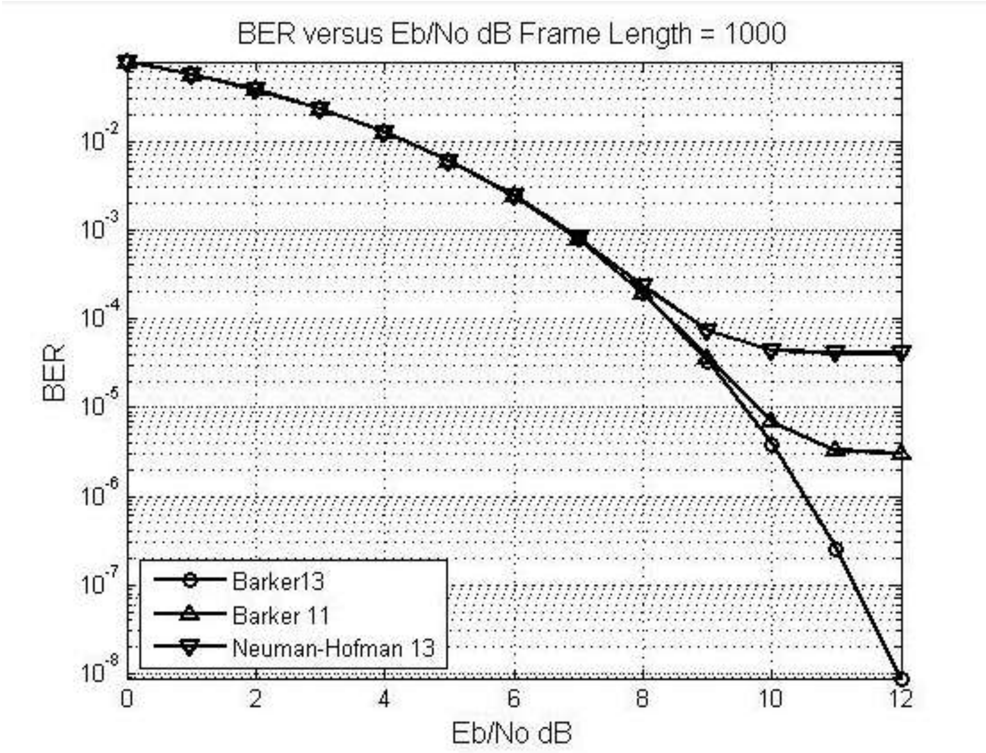


Figure 6 BER vs. SNR Frame Length = 1000 symbol