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A Modified Binary Search Algorithm for Carrier Acquisition in DSB-SC Communication System

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Abstract— In all DSB-SC (double side band- suppressed carrier) communication systems, acquisition of carrier is a big challenge at the receiver. For DSB-SC modulation, the carrier is not transmitted because it consumes a lot of power but the information is carried only by the side band. A novel algorithm for carrier acquisition is introduced which is a modified version of Binary search Algorithm. This modified algorithm is a hybrid of Binary search tree and Modified search tree. The proposed algorithm proves more helpful for carrier acquisition process as it is more accurate, low cost and less time consuming. Also, the computational complexity is very low, instead of 80-82, needs only 13-14 multiplication for carrier acquisition.

Keywords- carrier acquisition, binary search, modified binary search, primary roots, modulated signal

I. INTRODUCTION

In this modern era of fast grooming communication century, almost all types of DSB-SC based communication systems are facing the problem of acquiring the fast and efficient carrier at the receiver side. During transmission, a carrier consumes a lot of power. Since, only the side bands contain the information about the message, carrier is suppressed. This results in a DSB-SC wave. Basically carrier acquisition or carrier recovery is the process of generating the carrier signal from local oscillator of receiver on the basis of frequency and phase difference of received signal's carrier wave. The method used to recover message signals from DSB-SC waveforms is known as coherent or synchronous detection (or demodulation). Carrier acquisition involves the acquisition of both frequency and phase [3]. In practical systems, frequency acquisition is performed first, leaving a signal constellation which is not rotating (or that rotates at a rate which is slow compared to the signaling rate) but has a constant phase offset that needs to be corrected by the phase synchronizer [3]. The phase synchronization problem is invariably divided into an acquisition and a tracking part. In many practical systems, tracking is done simply and efficiently in a decision-directed (DD) mode [1], [2], and it is the acquisition problem that is more problematic, especially in applications where no preamble is allowed.

Binary search algorithm can also be used to acquire the carrier in DSB-SC. A binary search divides a range of values into halves, and continues to narrow down the field of search until the unknown value is found. Binary search can be viewed as a simple guessing game in which one is given an ordered list and asked to determine an unknown target value by making queries of the form "Is the target value greater than *x*?"

Binary trees are a well-known data structure with expected access time O (log2n), where n is the number of nodes elements) stored in the tree. In an ordinary binary tree a decision on how to proceed down the tree is made based on a comparison between the key in the current node and the key being sought.

Efficient multiplier less realization of no recursive digital filters with constant fixed point coefficients has been an area of pervasive research interest due to its widespread applications in digital signal processing, control, computer graphics and telecommunications [6-9,10-12].Many algorithms-including the convolution of complex signals, autocorrelation, cross-correlation, as well as computation of the Discrete Fourier Transform (DFT) using Fast Fourier Transform (FFT) techniques are complex multiplication bound. The idea of transform-domain signal processing proved to be very efficient especially in adaptive filtering [5].

The paper is outlined as follows. In section II we have presented the hybrid technique of rapid acquisition of carrier through hybrid binary tree approach. Section III represents the pseudo code. Section IV compares the results of performance analysis of Hybrid binary technique with other commonly used carrier acquisition techniques. Finally in section V we present the main conclusions of the work.

II. CARRIER ACQUISITION

The method of carrier acquisition which we have used in this paper is a modified form of binary search algorithm. This modified search algorithm is a hybrid of two search algorithms which are:

- Binary search tree.
- Modified search tree.

Firstly the modulated signal is received by the receiver where it is analyzed to acquire carrier. The receiver consists of two sections. One section uses the binary search tree process while the other section uses the modified search tree. Firstly binary search tree is used for carrier acquisition method and secondly the modified search tree is used. The overall tree diagram is a real-time tree diagram and it is formed during the process of carrier acquisition.

This hybrid tree structure proves more helpful for carrier acquisition process as it is more accurate, low cost, less complex and less time consuming.

The flow diagram of the receiver is shown below.

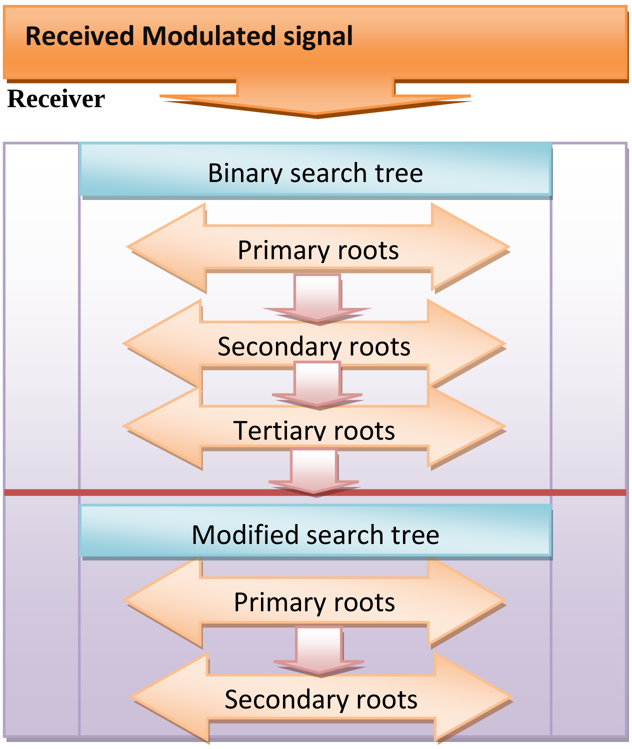

Figure 1. Flow Diagram

Both the sections are discussed below in detail. The first step involves the binary search tree method which is shown in Figure 2.

A. Binary search tree:

This search algorithm involves three steps for the carrier acquisition process. The process starts from the main root or the primary root. The main root is further divided into two sub roots called the secondary roots which are further divided into more sub roots known as tertiary roots. Each root or sub root consists of two nodes from which a root is linked.

One node is having a high frequency and the second one is having a low frequency. In primary roots there is just a single pair of two nodes. In the secondary roots there are two pairs of nodes while in the tertiary roots there are four such pairs. The pair which is to be selected is decided by the correlation method. Thus during the process of carrier acquisition only specific roots are selected that efficiently reduces the number of multiplications.

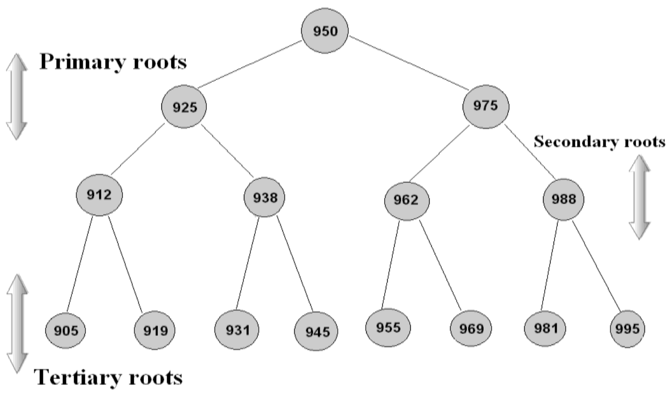

Figure 2. Binary Tree diagram

This algorithm works on the principle of basic vector multiplication. Maximum amplitude is obtained when the modulated signal is multiplied with that node whose frequency value closely matches with the modulated signal carrier frequency. Thus this algorithm intelligently detects that node (high frequency or low frequency node) near which the carrier frequency lies. The process starts from the primary roots. The nodes are multiplied with the modulated signal and the node giving maximum amplitude is marked as the primary node. The primary node is then multiplied with the received modulated signal. Again a maximum value is obtained at the node which is closest to the modulated carrier frequency. Thus that node is selected as the secondary node. Similarly the process is repeated thus giving the tertiary node. The selected node defines a new search area. Three steps are involved therefore to reduce search area nearly up to 82-87% with just six multiplications.

To further explain our search algorithm we take an example where we obtained a modulated signal of unknown carrier frequency within the range of 900-980Hz.

1) Process of binary search tree:

Let say the received modulated signal has a carrier frequency of 906Hz. In the primary roots of binary search tree the node '925' in the primary roots would be selected as it is nearest to the modulated signal carrier frequency. Similarly, the node '912' would be selected in the secondary roots and node '905' in the tertiary roots.

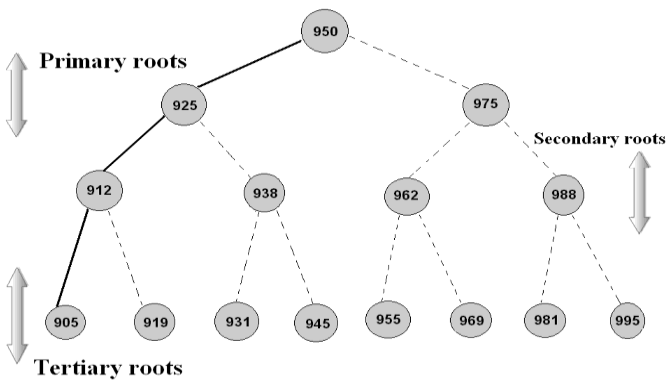

Figure 3. Binary search tree formation

a) Matlab results for binary search tree:

In the binary search tree includes the multiplication of the nodes having carrier frequencies '925Hz' and '975Hz' with the modulated signal. For this purpose carriers having the frequencies equal to node frequency are generated and multiplied with the modulated signal. Maximum amplitude is obtained at the node which is closest to the modulated carrier frequency. In this case the node selected would be '925'.

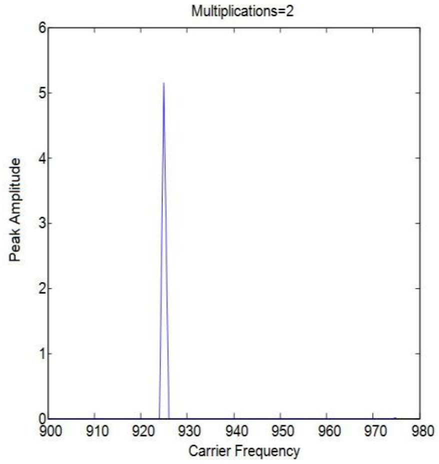

Figure 4. Primary roots(Binary Search Tree)

After detection through primary roots the signal moves on to secondary roots. There further two carrier signals having frequency equal to that of selected nodes are generated and multiplied with the modulated signal. Thus, the node ‘912’ is selected in this step as it is nearest to the received modulated signal carrier frequency. Figure 5 shows the detection of maximum amplitude at node with ‘912Hz’ carrier frequency.

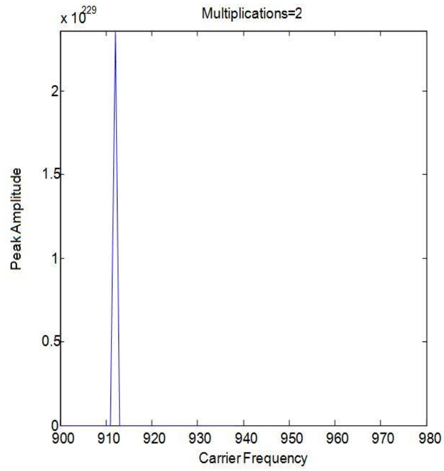

Figure 5. Secondary roots(Binary Search Tree)

On the third step the signal arrives at tertiary roots where further two nodes are selected for the acquisition process. These nodes are multiplied with the modulated signal and the maximum amplitude is observed. The node giving maximum amplitude is marked as the tertiary node. Figure 6 Shows that the maximum amplitude is detected at node with carrier frequency ‘905Hz’.

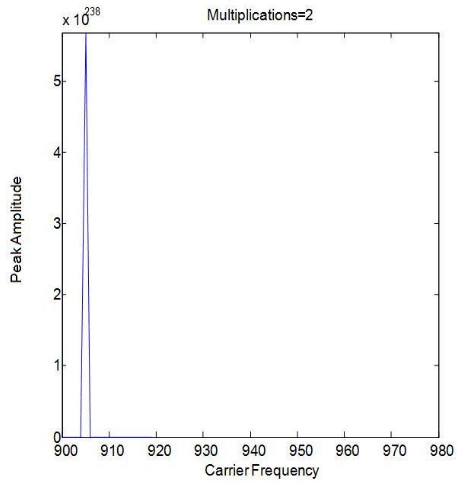

Figure 6. Tetiary roots(Binary Search Tree)

Two multiplications are involved in each branch of binary search tree. The overall process of binary search tree involved six multiplications.

The second step involves the modified search tree method which is shown in Figure 7.

B. Modified search tree:

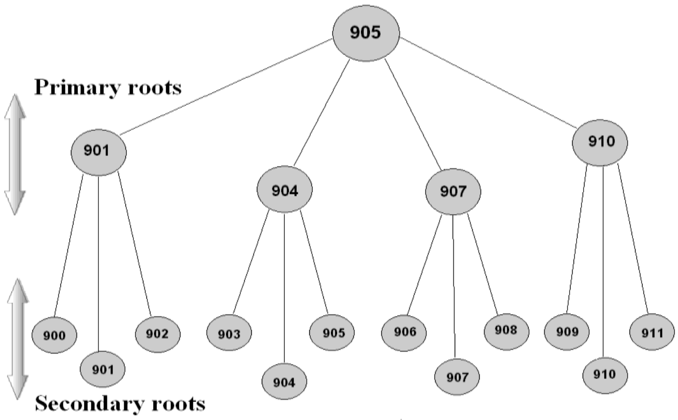

Figure 7. Modified Tree diagram

In the modified search algorithm an intelligent approach is used to acquire carrier. This algorithm is a hybrid of 'LOOP' structures. Figure 7 is a model of node '905'. Unlike binary tree structure this modified tree structure consists of only two roots. The primary roots and the secondary roots. Here the primary roots consist of four nodes instead of two showing two high frequency nodes and two low frequency nodes. The secondary roots consist of three nodes. One node represents high frequency, the other representing an intermediate frequency and the third one representing low frequency. In this modified algorithm each node is further selected by using the same approach as mentioned in Binary tree search thus reducing the search area further to 95-96% performing four multiplications at the primary roots and finally this novel algorithm detects the carrier frequency accurately by performing three or four multiplications further at the tertiary roots. Modified search algorithm thus performs a total of just 7-8 multiplications.

1) Process of modified search tree:

After completing the process through the binary search tree, the signal moves to the modified search tree. The primary root of the modified search tree involves four multiplications resulting in more efficient reduction of search area.

To explain this tree we continue our example. From the binary search tree our detected node was '905'. Our received modulated carrier frequency is 906Hz. Now we will see how this efficient algorithm detects the received carrier signal correctly.

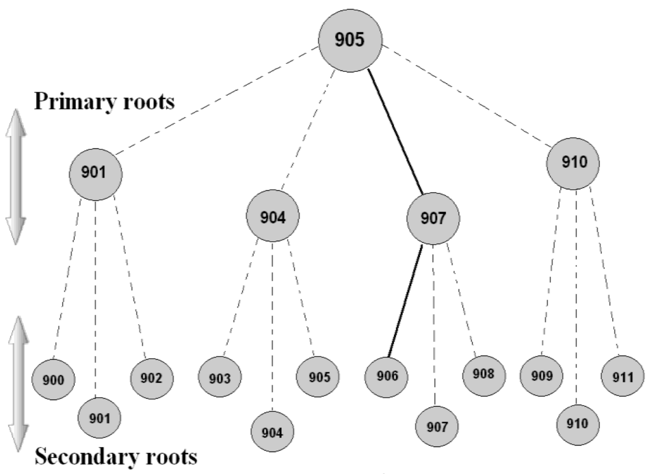

Figure 8. Modified search tree formation

At the primary roots four nodes are selected for the carrier acquisition process. These nodes are multiplied with the modulated signal and the node giving maximum amplitude is marked as the primary node. The node selected for the given example is '907'. On the secondary roots three nodes are selected further and are multiplied with the modulated signal. This step is the final step of the whole algorithm thus detecting the node with accurate carrier frequency of modulated signal. As a result of the multiplications performed by the tertiary roots the node with carrier frequency '906Hz' is selected as the carrier frequency.

a) Matlab results for modified search tree:

The selection of the starting node depends upon the marked tertiary node obtained from the binary tree algorithm. In this case the node selected for the modified algorithm to start with is '905' as shown in Figure 8.

In the primary roots of modified search tree four nodes are primarily selected and are multiplied with the modulated signal. Here the mat lab result shows two amplitudes. This result actually shows that our search area has been reduced to such an extent that more values for carrier frequency are arising but the correct carrier frequency is still detected by the maximum amplitude as we can see from the Figure 9. Hence the node selected at this step is '907'.

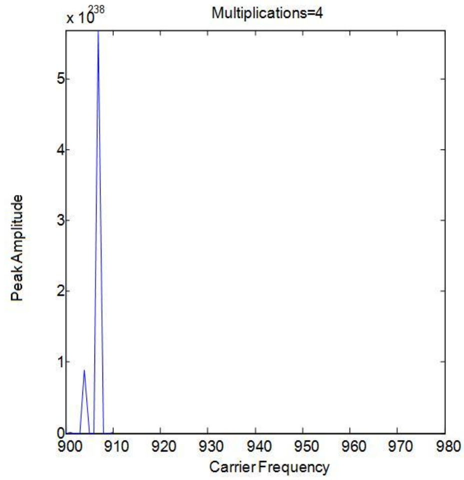

Figure 9. Primary roots(Modified Search Tree)

After this stage the search area is reduced to 96%.Node with the maximum amplitude is selected. After detection through the primary roots the signal passes to the final stage i.e. secondary roots.

In secondary roots of modified search tree three multiplications are involved to detect the modulated carrier frequency accurately. Figure 10 shows that a single peak is obtained at the carrier frequency 906Hz. Thus at this final step the carrier frequency of the modulated signal is detected accurately.

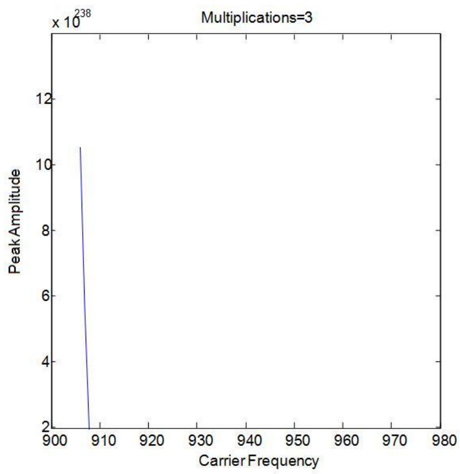

Figure 10. Secondary roots(Modified Search Tree)

III. PSEUDO CODE

Receiver

```
while (! End data ())
{
Modulated signal received
Step 1

for (i->two-mid-valued-frequencies)
Generate carriers on these frequencies
Correlating input signal
Plot vector
}
Save index of max(vector)
Index=k
{
for (i->two-frequencies-equally-spaced-from-k)
repeat Step 1
}
Index=k1
{
for (i->two-frequencies-equally-spaced-from-k1)
repeat Step 1
}
Index=k2
{

Step 2

for (i->three-frequencies-equally-spaced-from-k2)
perform three multiplications
save amplitudes in the vector
Plot vector
}
Index=k3
{
for (i->three-frequencies-equally-spaced-from-k3)
repeat Step 2
}
Plot vector
Note index with maximum amplitude
Index->carrier frequency

Carrier acquired
```

IV. RESULTS AND COMPARISON

Future of fast communication systems demands efficient techniques which employs least complexity with better results. In this section we compare the technique for carrier acquisition mentioned above with a number of other techniques to prove the efficiency, reliability and performance of this technique to the readers. The purpose of this paper is to introduce a new algorithm with least number of computations and better results.

The digital modulation/Demodulation techniques enable the efficient spectrum usage by dividing the bandwidth into transmission channels. Different coherent detection methods are used for the carrier acquisition depending upon the different modulation techniques.

In fast fading environments differential detection [13] and frequency discriminator detection [14]-[16] are considered an effective technique for obtaining reliable transmission performance. But on the other hand differential detection offers a delay of 10-150 ps in the intermediate frequency band due to the use of shit-registers. Therefore, greater power consumption, delay line without automatic control and with large intersymbol interference degraded its performance. Discriminator intelligently detects the carrier even in random FM noise conditions. Due to abrupt phase variations frequency discriminator detection is not reliable for QPSK signals. Coherent detection [17] is suitable for mobile radio applications due to its low power consumption and good BER performance in slow fading environment as compared to the differential detector. However, it is difficult to apply it to burst signal transmission.

To overcome the problems in above three detection techniques, dual-mode carrier recovery (DCR) circuit was designed. The DCR circuit adaptively selects one of two operation modes according to the fading environment: one is the conventional Costas loop mode; and the other is the adaptive carrier-tracking (ACT) mode [18]. This ACT mode controls the reference phase digitally, and enables instantaneous phase tracking in the carrier recovery process [19]. Even under fast fading conditions, the BER of coherent detection using ACT is equivalent to that of differential detection. In addition, ACT'S instantaneous phase tracking characteristic is applicable to fast carrier frequency acquisition in burst signal transmission. Therefore, for good BER performance and application to burst signal demodulation, the DCR coherent demodulator is superior to a conventional coherent demodulator or a differential detector [19].This will increase the complexity of the circuit which increases the cost and complexity of algorithm for computations. Therefore need of demodulator which offer less computations becomes necessary.

Similarly multiple-symbol differential detection (MSDD) was first proposed for detecting multiple phase-shift keying (M-PSK) signals transmitted over an additive-white-Gaussian noise (AWGN) channel [20]. The main advantage of MSDD is that it does not require a coherent phase reference at the receiver (it does require, however, the ability to measure relative phase differences) [21]. MSDD performs maximum-likelihood detection of a block of information symbols based on a corresponding observation interval [21]. The method was presented as a bridge of the gap between the performance of coherent detection of M-PSK and conventional differential detection of -ary differential phase-shift keying (M-DPSK) [20]. In the course of designing simulations for evaluating MSDD it was realized that there is no efficient MSDD algorithm available for MSDD with diversity [21]. The computational complexity of direct computation of the decision statistic grows exponentially with the number of symbols in the observation interval [21].

The numbers of computations in discrete Fourier transform (DFT) can be reduced using Fast Fourier transform (FFT). For computing one sample, we require N0 complex multiplications and N0 – 1 complex addition. In FFT we take the value of N_0 in the power of 2's.For large N0, this can be prohibitively time consuming, even for high speed computer.

V. CONCLUSIONS

Finally, it is concluded that the modified Binary Search Algorithm is an efficient approach for carrier acquisition in DSB-SC communication System. The proposed algorithm proves more helpful for carrier acquisition process as it is more accurate, low cost and less time consuming. Also, the computational complexity is very low, instead of 80-82, needs only 13-14 multiplication for carrier acquisition.

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