Design of New Spreading Sequences based on MC CDMA for WiMAX

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***Abstract*— In this paper we have designed and simulated New Spreading Sequences which shows the properties similar to that of both Gold sequence and Kasami sequences. These Spreading Sequences help in reducing the Multiple Access Interference (MAI) present in DSSS by a large value. Use of this modified Spreading Sequences make sure that MCCDMA[1] technique can be used efficiently in WiMAX and its performance is better than presently existing technologies. To get the desired results we have analyzed the existing sequences like m sequences, Gold sequences and Kasami Sequences. We implemented and compared Gold sequences with the newly generated spreading sequences. The proposed sequence generator simulated circuit will be little bit complex than the Gold sequence generator but less than the Kasami sequence generator and the performance of the New spreading sequence generator is better than the existing sequence generators.**

Keywords-PN sequence; Gold sequence; Multiple Access Interference (MAI;, Direct Sequence Spread Spectrum (DSSS); Multi Carrier Code Division Multiple Access (MCCDMA); Orthogonal Frequency Division Multiple Access (OFDMA).

I. INTRODUCTION

Recently Spreading Sequence finds applications in Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum Signaling in which the multiplexed signals of different channels are coded with Spreading Sequences. Generally used Spreading sequences in CDMA are m sequences, Gold Sequences and Kasami Sequences. All of these mentioned Sequences have only moderate orthogonality due to Multiple Access Interference (MAI) present in all the technologies based on CDMA. This makes performance of CDMA worst when used in peak time.

WiMAX is Wireless Broadband Access Technology which comes under IEEE 802.16 standards. It is presently based on OFDMA but it gives its best performance when it is implemented in MC CDMA. Since MC CDMA is the combination of both OFDM and CDMA we have to use Spreading Sequences to multiply the data signals on different channels. Generally used data Spreading Sequences are m sequences, Gold Sequences and Kasami Sequences but they have moderate orthogonal property and they are not good enough in terms of their Cross Correlation as well as Auto Correlation property. Due to this an unwanted interference called Multiple Access Interference comes into picture which makes WiMAX to work with limitations, and gives it a worst performance when it is used in peak time. But if we are able to design special Spreading Sequences which have higher orthogonality, improved Cross Correlation as well as auto Correlation properties than the existing sequences, then the performance of WiMAX in MC CDMA will be far much better than the performance of WiMAX in OFDMA and would be able to give higher data rates for every member accessing the bandwidth at the same time. Thus WiMAX can be used undisputedly for Wireless Broadband Access by a large number of people accessing the same bandwidth at the same instant of time with high data rates. Here in this paper we have designed new modified Spreading Sequences which have higher orthogonality and have higher Cross Correlation as well as higher Auto Correlation property. Due to this the Performance of WiMAX is improved by a larger than its performance when present Spreading Sequences like Gold Sequences and Kasami Sequences are used. A comparative study of the performance of MC CDMA based WiMAX is presented by writing the MATLAB code to simulate its performance by using presently existing Spreading Sequences like Gold Sequences and Kasami Sequences and comparing the results with the results obtained by using new Modified Spreading Sequences.

II. FREQUENTLY USED SPREADING SEQUENCES

Spreading Sequences are nothing but the particular combination of 1's and 0's in a random fashion or in a organized fashion. They are generated by using linear feedback shift registers in a particular fashion and XORing the contents with the cyclic shifting of one or all the registers together. In present time, frequently used sequences are maximum length sequences, gold sequences and kasami sequences.

Since WiMAX in MC CDMA technique can carry the huge amount of traffic at the same time in the same bandwidth but for this the spreading sequences that are used for modulation purpose should be highly orthogonal to each other with almost zero cross correlation.And since large number of users access the same bandwidth so there should be a method that can produce the large number of sequences with the simplest possible model.

Above said presently used sequences are not highly orthogonal and also some of the sequences like maximum length sequences produces less number of spreading sequences for the sufficient length of feedback shift registers due to which WiMAX in MC CDMA does not give the ideal performance as it is expected, so it gives the scope for designing of the new spreading sequences.Here is the explanation of generation of presently used sequences and newly designed sequences.

Maximal length sequence (m-sequence) is generated by using linear feedback shift register and exclusive OR gate circuits. A simple block diagram of m-sequence generator circuit having 3 D flip-flops as an example is shown in Fig1.:

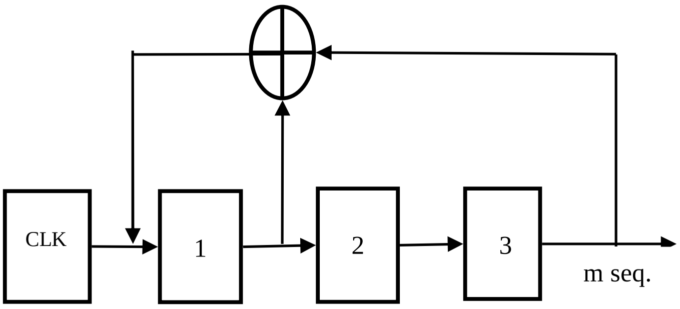

Figure 1. m-Sequence Generator

Here we have taken feedback register of length m=3, and primitive polynomial used here is $g(x) = 1+x+x^3$. After simulation we get the corresponding set of 3 sequences of period 7, so for the register feedback of length 3 we are getting only 3 sequences so number of sequences produced are very less in number so it is not coming true in WiMAX based on MC CDMA where large number of sequences required for large number of transmissions simultaneously. Moreover the orthogonality between the m sequences produced is not good so these are not efficient for the WiMAX based on MC CDMA.

Kasami Sequence sets are the one of the important types of binary sequence sets because of their very low cross- correlation. Kasami codes are based on PN codes of length $N=2^m-1$, where m is an even integer. To generate Kasami Sequence, first of all the sequence a’ is found by selecting every $(2^{n/2}+1)$st bit of an m-sequence a. The resulting sequence a’ is an m-sequence. The first kasami sequence can be found by adding (modulo-2 addition) the sequence a and a’. Then by adding all $2^{n/2}$-2 cyclic shifts of sequence a’ with the sequence ‘a’, a new set of kasami sequences can be formed.

For example for the case m=4, we take 15 bit length PN code and take its every 5^{th} bit and keep repeating it to find the sequence a’. The first member of the code is found by adding a with a’ which is shown in figure 1.2. We then shift the kasami code by one bit and produce the member of the set.

15 BIT KASAMI CODE **1** 1 1 1 0 **1** 0 1 1 0 **0** 1 0 0 0

3 BIT KASAMI CODE 1 1 0, 1 1 0

Figure 2. Generation of Kasami Sequences.

For zeroth shift of kasami code-

Sequence a: **1** 1 1 1 0 **1** 0 1 1 0 **0** 1 0 0 0
Sequence a’: 1 1 0 1 1 0 1 1 0 1 1 0 1 1 0
First kasami sequence: 0 0 1 0 1 1 1 0 1 1 1 1 1 1 0

For first shift of kasami code-

Sequence a: **1** 1 1 1 0 **1** 0 1 1 0 **0** 1 0 0 0
Sequence a’: 0 1 1 0 1 1 0 1 1 0 1 1 0 1 1
Second kasami sequence: 1 0 0 1 1 0 0 0 0 0 1 0 0 1 1

And thus shifting the kasami code for third time we can again generate the kasami sequences. After this again take the second m-sequence and do the same operation again by shifting the kasami code shown in fig1.2, thus for m length of shift register we can generate m*n sequences in total where $n=2^m-1$. So here we see that for even feedback registers of length 4 we can produce 45 spreading sequences each of length equal to 15 bits, and through the simulation results we see that the kasami sequences produced have the higher orthogonality than the m-sequences.

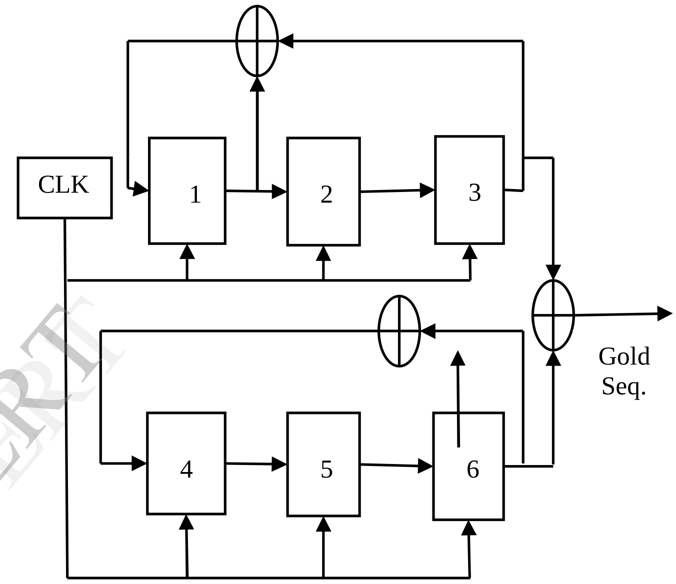

Figure 3. Generation of Gold Sequences

Gold sequences are also the widely used spreading codes that are used for data modulation purpose. They are generated in the same way as m-sequences generates with the only difference that in place of one feedback register we have to take more than one feedback register in which m-sequence of one will be fixed while other goes through the periodic time shift and thus produces 2^m-1 sequences for the m length of the shift register. For the case of m=3, we can see in Fig. 3.

Here, m-sequence produced by the first feedback shift register is made constant while the each m-sequence produced by the second feedback shift register is time shifted periodically in the period of $7(2^m-1)$ and thus total of 9 spreading sequences are produced in which each having the period of 7. Gold sequences produced are better than m-sequences because with the same length of feedback shift register we can produce more number of spreading sequences and they are also better in terms of lower cross-correlation value between different sequences. Gold sequences are just comparable with the kasami sequences.

III. GENERATION OF NEW SPREADING SEQUENCES

The new modified gold sequence is also generated by using the preferred pair of sequences. Here also we have taken the polynomial of degree 3 as an example. Instead of just using Ex-OR gate first we add the two sequence which will give another sequence and after that use Ex-OR gate with this sequence, the output of which is also a periodic sequence. The block diagram of the circuit is shown in fig 4.

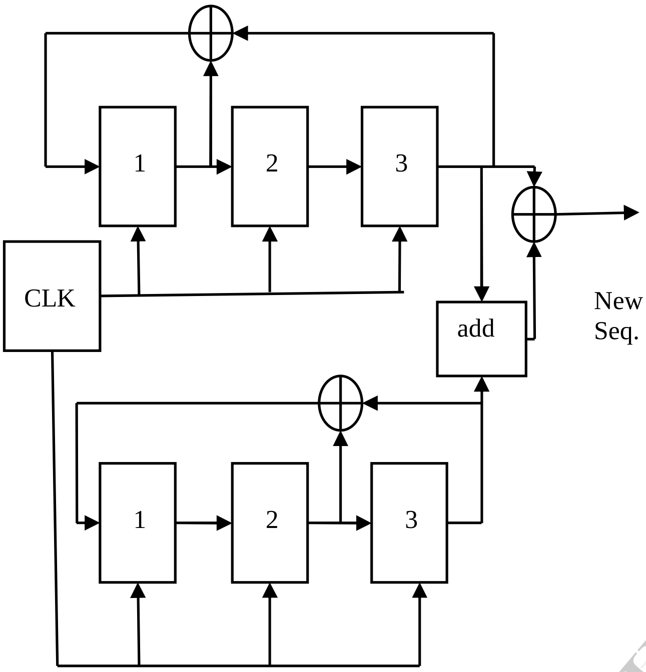

Figure 4. New Spreading Sequence Generation

We have done this modification to get more no of sequence easily. The circuit design complexity will also be reduced compared to other sequence generator with this modification.

Through simulation results, it is proved that by using newly designed spreading sequences, the performance of WiMAX in MC-CDMA is better than if we use m-sequences, Gold sequences or Kasami sequences for modulation purpose. These sequences are easy to construct.

New Spreading Sequences are also better than the existing ones in the sense that they generates the large number of sequences for the same length of the register, allowing many users to occupy the same bandwidth, and thus helps in easier circuitry for generation.

IV. IMPLEMENTATION OF NEW SEQUENCES BASED ON MC CDMA IN WIMAX

In present time the Wireless Broadband Access technology 'WiMAX' is mainly based on Orthogonal Frequency Division Multiple Access (OFDMA), but its performance is far much better if we implement Multi Carrier Code Division Multiple Access (MC CDMA) as a radio access technology. But practically it is seen that the performance of WiMAX in MC CDMA reduces if it works in peak time, it mainly happens due to the improper orthogonality of the spreading sequences we are using for modulation. So here in place of normally used Gold sequences and Kasami sequences we can directly use newly designed spreading sequences which have higher orthogonality than the pre-existing sequences, so finally the performance of WiMAX is improved by a large value.

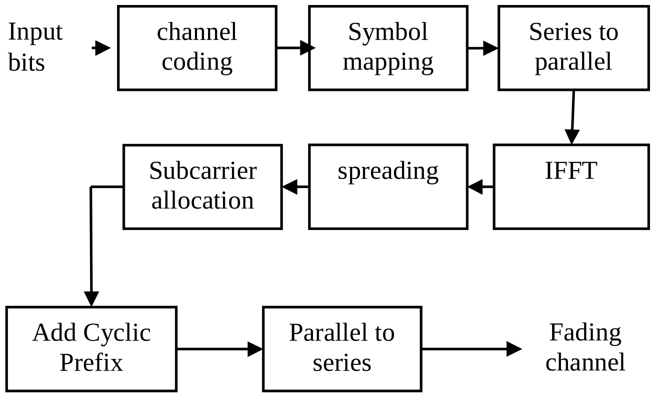

Figure 5. Transmitter Section

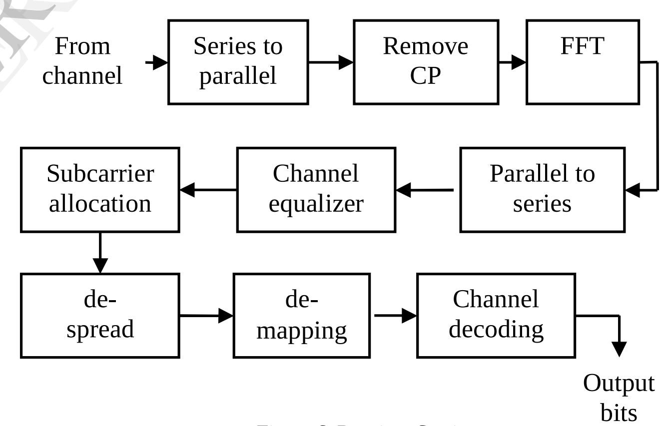

Figure 6. Receiver Section

These two block diagrams drawn above shows the full design of the WiMAX based on MC CDMA .

The simulation results shows that, when New spreading sequences are used for modulation in place of Gold sequences and kasami sequences then performance of WiMAX in MC CDMA increases by a larger value.

V. SIMULATION AND RESULTS

We have simulated the above generated new spreading sequences using MATALB coding tool. Through simulation we have got the auto-correlation and cross-correlation graphs for the newly designed sequences which shows they are the stronger contenders for using them in WiMAX based on MC-CDMA for modulation purpose.

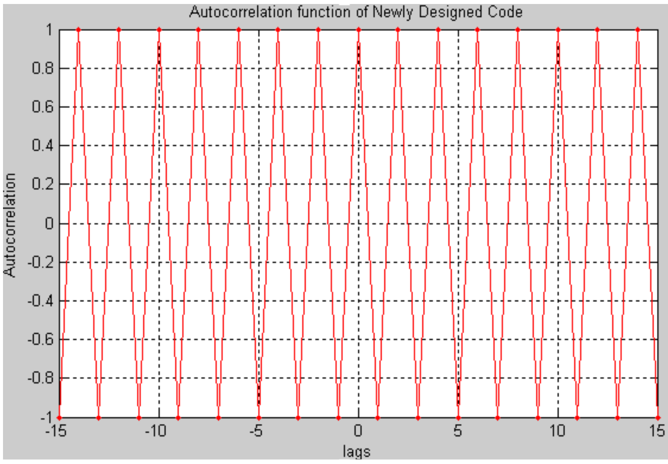

Figure 7. Auto-Correlation Function of Newly Designed Codes

Further by using simulation graphs we have compared the performance of WiMAX using newly designed sequences as well as Gold Sequences by using different modulation techniques, so finally it shows that performance of WiMAX is better in Newly Designed sequences.

Graph shown in Fig.7 tells that the autocorrelation function of the Newly Generated Sequences is periodic in nature which is the necessary condition to be satisfied by the spreading sequences. Graph in Fig. 8 and Fig. 9 shows that WiMAX is better if we implement it in MC CDMA than with OFDMA.

Also if we increase the Spreading Factor of the newly generated codes, its performance improves continuously. Fig. 8 shows the implementation using QPSK modulation technique and Fig. 9 shows the implementation using QAM 64 modulation technique.

Figs. 9, 10 and 11 show that the Bit Error Rate of WiMAX based on MC CDMA is better in New Spreading Sequences than the pre-existing sequences like Gold Sequences. So Performance of WiMAX is always better independent of their modulation through different modulation techniques.

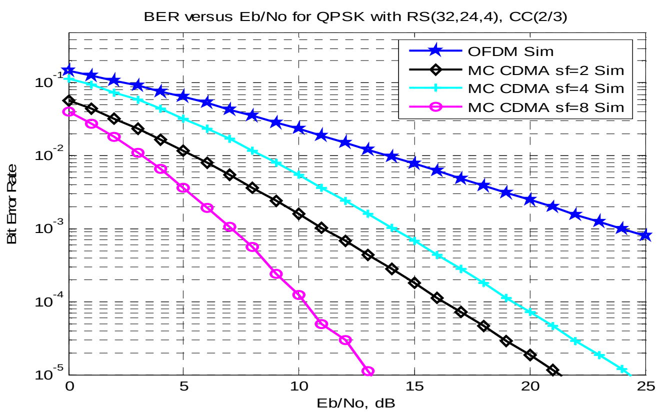

Figure 8. BER vs. E_b/N_0 for QPSK

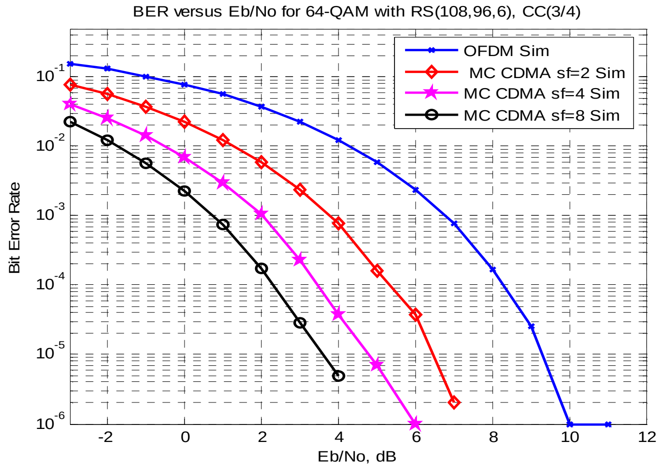

Figure 9. BER vs. E_b/N_0 for QAM 64

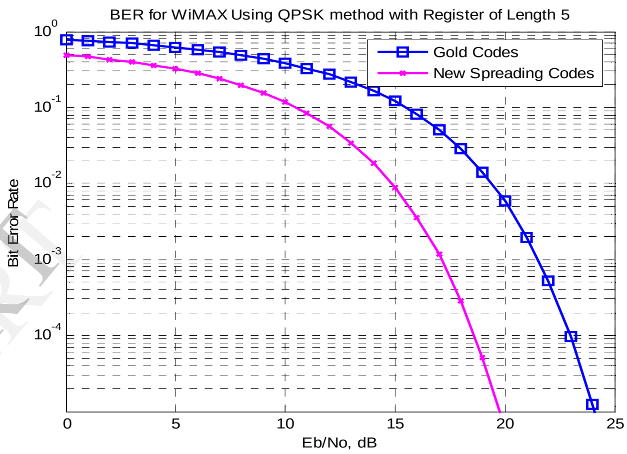

Figure 10. WiMAX in QPSK for Register length of 5

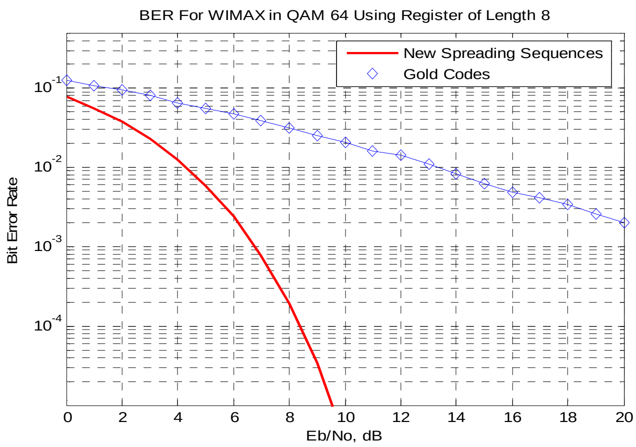

Figure 11. WiMAX in QAM 64 for Register length of 8

VI. Conclusion

Through simulation we have got the auto-correlation and cross-correlation graphs for the newly designed sequences which shows they are the stronger contenders for using them in WiMAX based on MC-CDMA for modulation purpose.

Further by using simulation graphs we have compared the performance of WiMAX using newly designed sequences as well as Gold Sequences by using different modulation techniques, so finally it shows that performance of WiMAX is better in Newly Designed sequences.

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