Cost Comparison of the Detection Techniques for Optical Spectrum CDMA System

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Summary
The advantage of employing the subtraction detection technique in the optical spectrum code division multiple access (OSCDMA) has been largely recognized. In this paper, the comparison between the complementary and AND subtraction detection techniques for the OSCDMA in terms of cost and performance is investigated as they are very important factors in optical communication systems. Result of SNR/cost shows that the AND subtraction detection technique tends to increase when the number of weights increases.

Key words:
Detection technique, Optical Spectrum CDMA, cost, KS (Khazani-Syed) code

1. Introduction

OSCDMA technique is one of the multiplexing techniques that is becoming popular because of the flexibility in allocation of channels, ability to operate asynchronously, enhanced privacy and increased capacity in bursty nature networks. The performance of OSCDMA strongly depends on the codes properties and the detection technique. The codes are designed in such a way to be sufficiently different that the probability of mistaken one code from another is very low. Unfortunately, when many users are actively transmitting, many overlaps may result. A receiver may then erroneously conclude that its target code was sent. This phenomenon is known as an error arising due to multiple access interference (MAI) or multiple user interference (MUI) [1, 2]. As more users share the channel simultaneously, the effect of MAI becomes more significant. MAI is one of the dominant causes of performance degradation in OCDM systems. Therefore, the choice for the type of codes according to their statistical properties is also quite important although there is no perfect code for every application.

The effect of MAI can be eliminated by using subtraction detection technique. The most common subtraction detection technique is the complementary subtraction detection technique, which is also known as balanced detection technique [3, 4]. However, since the use of power at the balanced photodiode is different with different number of active users, it is hard to predict the MAI value in normal operation conditions where the number of users fluctuates over time. Therefore, it is extremely important to design a detection technique in such a way that MAI is minimized regardless of the number of users and maintain the performance of the system at the minimum cost.

In most researches [5, 6, 7], complementary method has been used at the receiver side to recover the original signal. However, [8] and [9] have proposed AND subtraction detection technique which provides a better performance than complementary subtraction. In this paper, we report the cost comparison between these two detection techniques. The KS (Khazani-Syed) [10] code family which is a unified code construction based on Double Weight (DW) and Modified Double Weight (MDW) [11, 12] was used in this investigation.

2. Detection Techniques

2.1 Complementary Subtraction Detection Technique

The complementary subtraction detection technique was first proposed by Kavehrad and Zaccarin [13]. The implementation of the system using complementary subtraction detection technique is shown in Figure 1. Optical bandpass filters are used as the encoders and decoders for all detection techniques that will be discussed in this paper. For example, let us consider the KS code sequences as shown in Table 1.

Table 1. KS code with weight, W=2

	CODE SEQUENCE			
	λ_1	λ_2	λ_3	λ_4
X	1	1	0	0
Y	0	1	1	0

Note that λ_i where *i* is 1, 2, ...N, represents the spectral position of the chips in the KS code sequence.

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The optical pulses are encoded according to the KS code sequence and then the code is optically modulated with the data. For example, the KS code sequences shown in Figure 1 are denoted as X= (1100) and Y= (0110). The outputs of the two optical external modulators (OEMs) are combined and transmitted through an optical fiber. Referring to Receiver 1, the signals are split and decoded separately by two complementary decoders. The outputs from the complementary filters are detected by the two photodetectors (PIN) connected to a subtractor. In order to decode two code sequences of KS code and detect the signal, this technique requires five filters, four photodetectors and two subtractors. Three filters with the bandwidth twice the chip width for λ_1 and λ_2, λ_3 and λ_4, λ_2 and λ_3 and two separate filters for λ_1 and λ_4. To eliminate the MAI from undesired users, an attenuator is required at PIN 2 and PIN 4.

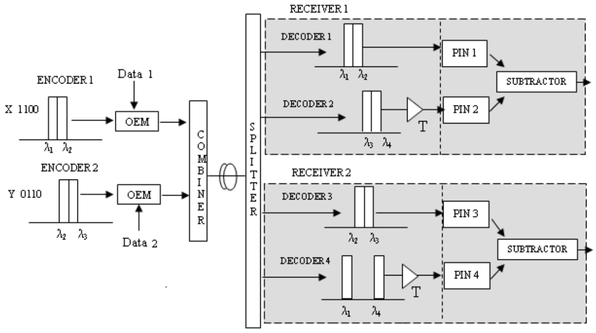

Figure 1. The System using Complementary Subtraction Technique

2.2 AND Subtraction Detection Technique

The system using AND subtraction is shown in Figure 2. The difference between the complementary and the AND subtraction technique is at the decoders of the receivers. The filters for Decoders 1 and 3 of the receivers for AND subtraction detection technique are the same as the complementary subtraction technique shown in Figure 1. However for the system using AND subtraction detection technique, the filters for Decoders 2 and 4 are placed at λ_2, which is the overlapping chip of the two code sequences. The overlapping chip of the two code sequences may cause interference at the receiver [14].

The advantage of AND subtraction detection technique is that it requires less number of filters compared to the complementary subtraction technique. It can be seen that the number of filters is reduced to four as compared to five filters that are required when using the complementary subtraction detection technique. Two filters with bandwidth twice the chip width for λ_1 and λ_2, and λ_2 and λ_3, and two filters at the position of the overlapping spectra occurring in the code sequences, that is λ_2. The number of photodetectors and subtractors are the same as required in the complementary technique. However, no attenuator is required to eliminate MAI.

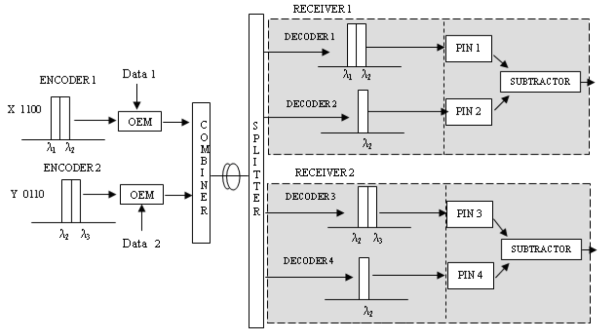

Figure 2. The System using AND Subtraction Technique

3. Cost and Performance Comparison between the Detection Techniques

The implementation of complementary and AND subtraction has been described in the previous sections. It is obvious that the advantage of AND subtraction is that fewer number of filters are required for the decoders. The number of filters that is needed in the decoders depends on the code weight, W and the basic code's row size or the basic number of users, K_B. Moreover AND subtraction detection technique does not require attenuator to eliminate MAI. Therefore, the use of fewer components to implement the AND subtraction technique leads to a substantial cost reduction of the overall system. For complementary subtraction, the filters that are needed at the decoder can be determined as:

$$F_{Comp} = (W \times K_B) + (K_B - 2) \quad (1)$$

As for AND subtraction, the filters that are needed can be determined as:

$$F_{AND} = W \times K_B \quad (2)$$

Figure 3 illustrates the number of filters for the decoders as the code weight increases for two users. The number of filters increases as the code weight increases. It is clear that complementary subtraction technique requires more filters than the AND subtraction technique. For example, for weight equals to 10, complementary and AND subtraction techniques require 21 and 12 filters, respectively.

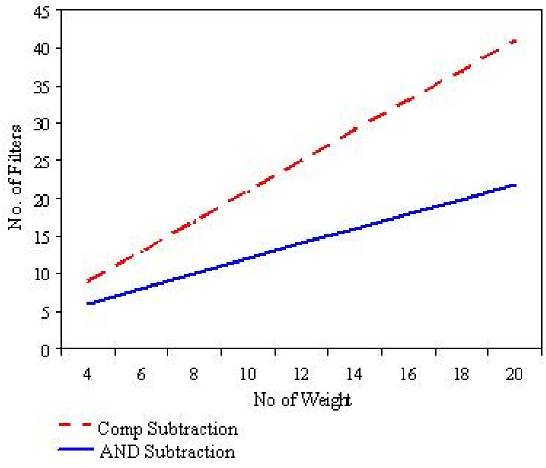

Figure 3. Number of Filters Required for Two Users for Complementary and AND Subtraction Detection Techniques as the Code Weight Increases

Comparing costs of the subtraction detection techniques can be done based on the number of filters that is required for the decoders. This cost evaluation does not take into account other components such as the encoders, optical sources and fibers, which are considered as similar to both of the systems. The price of available tunable optical filters and attenuator is assumed to be A and B, respectively, where B = 0.5A. Figure 4 shows the results of the cost components for the two subtraction detection techniques. It can be seen that the cost increases linearly with the code weight. The number of filters and cost will increase as the number of users increases.

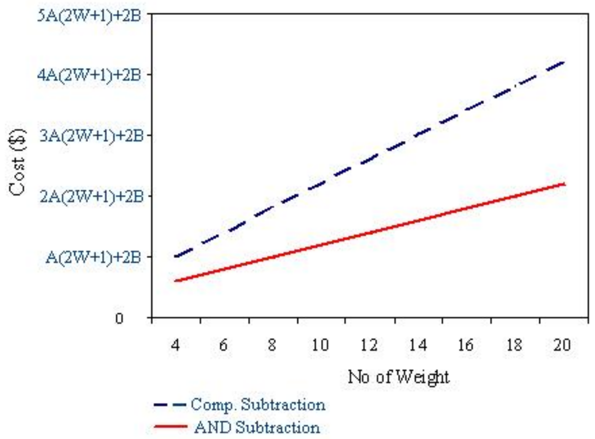

Figure 4. Cost for Two Users for Complementary and AND Subtraction Detection Techniques as the Code Weight Increases

The current price of commercially available tunable optical filter and attenuator that has been provided by the manufacturer is $5366 and $2590, respectively [15]. Therefore, for code weight W=10, the cost for the system using complementary and AND subtraction detection technique will be $117866 and $64392, respectively. Obviously, the complementary subtraction requires much higher costs than the AND subtraction technique.

Figure 5 shows the ratio of SNR to the cost components for the two subtraction detection techniques. It can be seen that when the code weight is less than 8, the SNR/cost for complementary subtraction is higher than the AND subtraction technique. It shows that theoretically it is advantageous to use the complementary subtraction technique for weight less than 8. However as the code weight increases greater than 8, the SNR/cost for the AND subtraction technique is higher than the complementary subtraction detection technique. This is because as the code weight increases, the number of filters and attenuators for the complementary subtraction technique are also increased to more than that required for the AND subtraction technique.

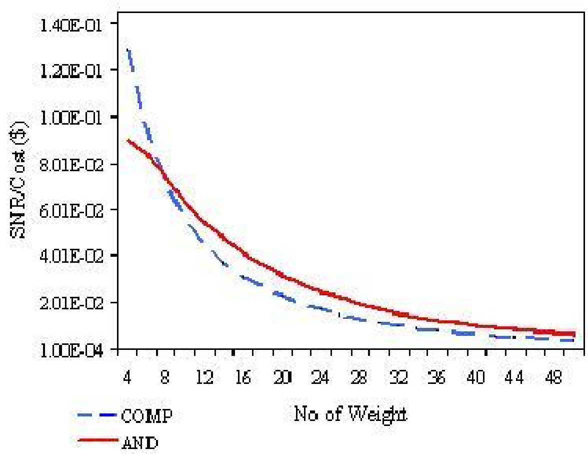

Figure 5. Ratio of SNR to Cost for Two Users for Complementary and AND Subtraction Detection Techniques as the Code Weight Increases

4. Conclusion

In this work, we presented a study on different type of subtraction detection techniques employing the KS code. Cost-comparison between the detection techniques has been performed. As described above, the implementation of AND subtraction detection technique is less complex and more cost-effective as compared with the complementary subtraction detection technique. The total power loss is reduced and the performance of the overall system improved significantly as described in [8, 9] for the AND subtraction technique. Consequently, complementary subtraction technique becomes no longer convenient as its economic advantages are reduced with increasing weight.

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