# Comparison of Detection Techniques in Optical CDMA Access Network for Point to Multipoint Configuration

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## Abstract

*In this paper, we are proposing a detection scheme known as spectral direct detection technique implemented with Fiber Bragg Grating (FBG) act as encoder/decoder. This FBG based is used to encode and decode the spectral amplitude coding namely modified double weight (MDW) code in Optical Code Division Multiple Access (OCDMA). This code is used due to its flexibility where its weight can be any even number that greater than two. Moreover, it can maintain the cross-correlation parameter equal to one. The performance of spectral direct detection technique against AND-subtraction technique which is both implemented with FBG based encoder/decoder is compared via simulation in downstream and upstream access network at point to multipoint (P2MP) configuration. The simulation will be carried out using OptiSystem version 6.0 and the performance is characterized through bit error rate (BER) and power received at various bit rate.*

## 1. INTRODUCTION

In optical CDMA systems, the detection process affects the design of receiver and transmitter. Basically, there are two types of detection technique; coherent and incoherent. The coherent detection technique refers to detection signal with knowledge of phase information of the carrier, while incoherent detection technique is reversely from coherent detection technique. By referring to incoherent detection technique, this technique does not need phase synchronization. Therefore, it will reduce the hardware's complexity of the systems. Due to this advantage, we prefer to choose incoherent detection technique rather than coherent detection technique for this paper.

In optical systems, rectangular filters are used as the encoder/decoder in front of LED in order to narrow down the linewidth before transmission [1]. In this paper, we used Fiber Bragg Grating (FBG) as encoder/decoder because it acts as a perfect filter. In FBG based encoder/decoder, the strain and temperature that introduced to the grating have direct effect to the Bragg wavelength [2-4]. Thus, the value of the Bragg wavelength of the FBG will be shifted by these two elements. Generally, the existing Optical CDMA coding scheme are using an arrayed of FBG as the encoder and decoder to provide an all-optical signal processing to the systems and a balanced photo detection scheme at the receiver [5].

Recently, AND-subtraction technique is used to replace complementary method at the receiver side. In this paper, we employed spectral direct detection technique because we want to eliminate the multiple access interference (MAI). MAI is the dominant source of deterioration in OCDMA systems; thus good design of the code sequence and detection scheme [6-7] is important to reduce the effect of MAI. At the same time we used FBG as the replacement for filter as encoder/decoder. This new approach is to reduce the complexity of the systems, improve the BER and at the

same time decrease the number of FBG as encoder/decoder.

## 2. THEORY

### A. AND Subtraction Detection Technique

In AND subtraction technique [8], the cross-correlation $\theta_{\overline{XY}}(k)$ is substituted by $\theta_{(X\&Y)Y}$, where $\theta_{(X\&Y)}$ represents the AND operation between sequences *X* and *Y*. For example, let X = 1011 and *Y* = 0110 and therefore (*X* AND *Y*) = 0010. Example of an AND receiver is shown in Figure 1.

At the receiver,

$$Z_{AND} = \theta_{XY}(k) - \theta_{(X\&Y)Y}(k) = 0 \qquad (1)$$

Equation (1) shows that, with AND subtraction technique, the multiple access interference or the interference from other channels can also be cancelled out. This subtraction technique can be implemented with any OCDMA codes, but for comparison purposes, the Modified Double Weight (MDW) code [9] is used as an example.

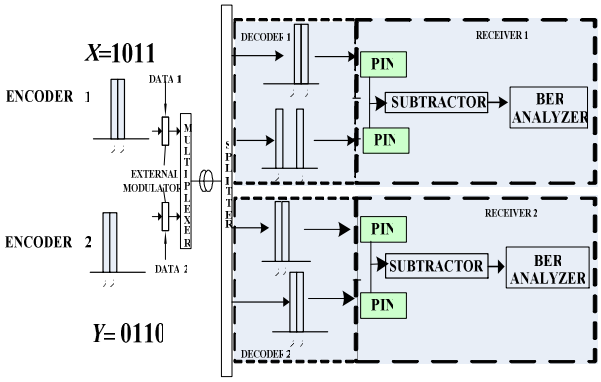


**Figure 1: Implementation of the AND Subtraction Technique**

### B. Spectral Direct Detection Technique

The implementation of spectral direct detection technique is completely different from AND subtraction detection technique. Figure 2 shows the implementation of spectral direct detection technique.

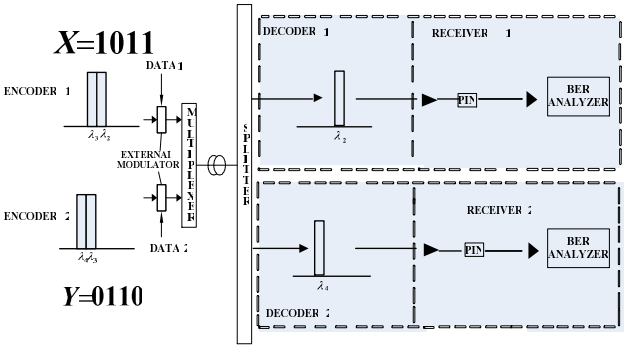


**Figure 2: Spectral direct detection technique for optical spectrum CDMA**

For this detection scheme, only wanted spectral chip in the optical domain is filtered. This detection scheme doesn't need subtraction detection technique at electric side. Therefore, MAI and Phase Induced Intensity Noise (PIIN) will not exist in this detection scheme. Nevertheless, this technique is only applicable to codes, which the spectral chips are not overlapped with other spectral chips of the other channel, i.e. a minimum of one clean chip in every code sequence. MDW and modified frequency hopping (MFH) [10] are the examples of codes that have this property.

## 3. SIMULATION SETUP OF OPTICAL CDMA

The setups of the detection scheme with MDW are illustrated in Figure 3 and 4 respectively for point to multipoint network. The ITU-T G.652 standard single mode optical fiber is used in the simulation. Table 1 shows the parameter values used for the simulation of the OCDMA system.

The dispersion, attenuation and the nonlinear effects of the optical fiber are all activated and specified according to the typical industry values to simulate the real environment as close as possible. The noises generated at the receivers are set to be random and totally uncorrelated.

**Table 1. Parameter values used for experimental simulation**

| Parameter | Value (Downstream) | Value (Upstream) |
|---|---|---|
| Length of fiber | 20 km | |
| Broadband source transmitted power | 16.4dBm | |
| Bit rate | 155 Mbps, 622 Mbps , 1.25 Gbps and 2.5 Gbps | |
| Wavelength | 1550nm | 1310 nm |
| Attenuation coefficient | 0.25dB/km | 0.35dB/km |
| Chromatic dispersion coefficient | 18ps/nm-km | 3.5ps/nm-km |
| Polarization mode dispersion coefficient | 0.07ps/√km | |
| Dark current | 5nA | |
| Thermal noise coefficient of the photo detector | $1.8x10^{-23}$ W/Hz | |

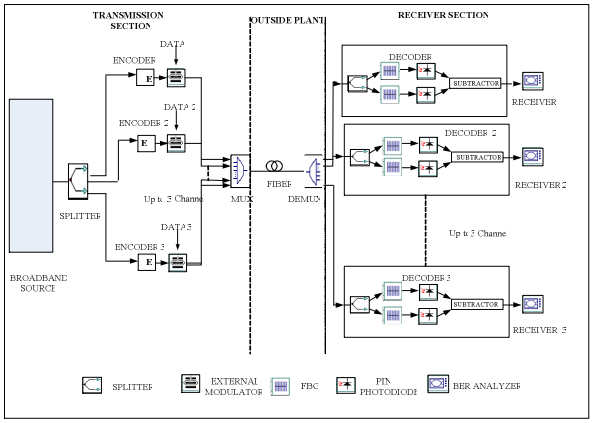


**Figure 3: Point-to-Multipoint Network Simulation Setup for AND Subtraction Detection Technique**

At the receiver side of the system, the incoming signal splits into two parts, one to the decoder that has an identical filter structure with the encoder and the other to the decoder that has AND filter (Figure 3) structures. A subtractor is then used to subtract the overlapping data from the intended code. For spectral direct detection technique (Figure 4), there will be no subtractor used to subtract the overlapping data. In this detection scheme only desire spectral chip in the optical domain is filtered. The results taken after the subtraction are discussed in the next section.

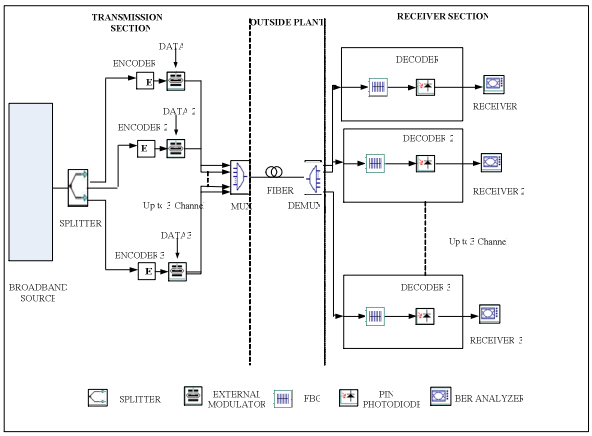


**Figure 4: Point-to-Multipoint Network Simulation Setup for Spectral Direct Detection Technique**

## 4. RESULTS AND DISCUSSIONS

Figure 5 and Figure 6 shows the results of experimental simulation using AND subtraction detection technique and spectral direct detection techniques for point-to-multipoint network in downstream and upstream direction at various bit rate. The distance was set at 20 km.

By increasing the bit rate, it will decrease the pulse width; consequently, changing the bit rate will affect the received signals. Figure 5 shows the performance of spectral direct detection technique and AND subtraction detection technique for BER against various bit rate.

From Figure 5, the performance of both detection schemes will decrease with bit rate. For downstream direction, the BER for spectral direct detection technique has better performance compare to AND subtraction detection technique. The effect of (multiple-access interference) MAI caused (phase-induced intensity noise) PIIN. The effect takes place due to the use of subtractor at receiver side in order to eliminate the noises imposed by the interference. Therefore, the BER performance for AND subtraction detection technique is slightly higher than BER performance for spectral direct detection technique.

From the graph we can see that the acceptable bit rate for both techniques is 1.25 Gbps for downstream application. While for upstream, at 2.5 Gbps it still shows a considerable reading which is $1x10^{-9}$. This is due to different attenuation and dispersion for 1550 nm and 1310 nm will cause different result for downstream and upstream direction. The attenuation at 1310 nm (upstream) was higher than attenuation at 1550 nm. Thus, the BER for upstream direction is higher than downstream direction. So, it clearly shows that upstream direction has higher BER than downstream direction due to the effect of attenuation and dispersion at different wavelength.

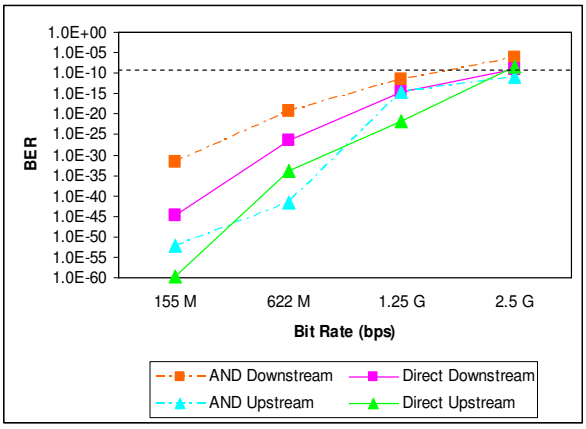


**Figure 5: BER versus bit rate for spectral direct detection technique and AND subtraction detection technique at 20 km for P2MP network**

The power received for both detection schemes is decreased due to increased of bit rate. Increasing the bit rate will decrease the pulse width, making the signal to be more sensitive to fiber dispersion and receiver circuitry noise. Figure 6 shows the performance of spectral direct detection and AND subtraction detection technique in different bit rate at downstream and upstream directions.

At 155 Mbps, the power received for spectral direct detection for downstream directions is about -49 dBm while for AND subtraction at same bit rate and directions, the power received is about -59 dBm. The power loss is high at AND subtraction detection technique is due to more FBG used as encoder/decoder. Thus, it is clear that spectral direct detection can support higher bit rate than AND subtraction due to the less power loss.

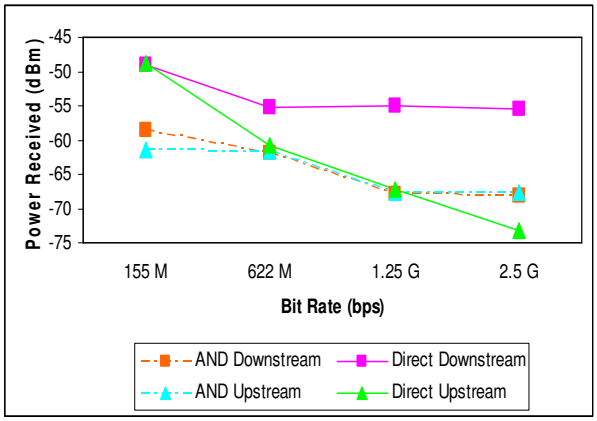


**Figure 6: Power received versus bit rate for spectral direct detection technique and AND subtraction detection technique at 20 km for P2MP network**

From the figure we can see that, the graph pattern for AND subtraction technique does not show so much different due to power loss between downstream and upstream application. However, for direct detection for upstream application it shows that the power received decreased sharply from 155 Mbps to 2.5 Gbps. Compared with direct detection for downstream direction it start to dropped steadily from -49 dBm to -55 dBm at 155 Mbps until 622 Mbps. After 622 Mbps the power received remain stable at -55 dBm. From these results, it can be seen that the power received at upstream is slightly lower compared to power received at downstream direction. These phenomena happened due to higher attenuation at 1310 nm where it is used as a center wavelength for upstream direction. Therefore, the power received at downstream is better than power received at upstream directions.

## 5. CONCLUSIONS

Generally, the performance of the OCDMA system is decrease as the bit rate is increased. This is because the effect of attenuation and dispersion in the fiber. In this paper, we have used spectral direct detection technique and it implemented with MDW codes with weight equal to 4. For this detection scheme, the performance of OCDMA is improved compared to AND subtraction detection technique. It has been proved from the result of the simulation. This is because effect of MAI and PIIN has been eliminated.

For overall performance, the spectral direct detection technique is better than AND subtraction detection technique. This is happened due to the number of FBGs used in spectral direct detection

technique is lesser compared to AND subtraction detection technique. Thus, the power loss of both designs especially for AND subtraction can be reduced if less number of FBGs are used. Therefore, the complexity, cost and total power loss of the systems is reduced.

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