

Fractional Optimal Golomb Ruler Based WDM Channel Allocation

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Abstract

A novel channel allocation method, based on optimal golomb ruler, that allows reduction of FWM effect while maintaining bandwidth efficiency, is presented. Simulation is carried out to show performance improvement in WDM systems without inducing bandwidth increase.

1 Introduction

In the attempt to reduce FWM^[1] effect in WDM systems, many unequally spaced channel allocation methods^[2-5] are proposed. However, they resulted in increase of bandwidth requirement compared to equally spaced channel allocation. This is due to the constraint of the minimum channel spacing between each channel and that the difference in the channel spacing between any two channels are assigned to be distinct. As the number of channels increases, the bandwidth for the unequally spaced channel allocation methods increases in proportion. A novel method for channel allocation is presented here to reduce the FWM effect so as to improve WDM system performance without inducing additional cost, in terms of bandwidth. A fractional bandwidth allocation algorithm is designed taking into consideration the concept of Optimal Golomb Ruler (OGR)^[6,7]. This proposed technique allows the gradual computation of system performance to result in an optimal point where degradation caused by interchannel interference and FWM is minimal. The method is simulated and the results are analyzed to prove its effectiveness, such that the system performance has improved while maintaining bandwidth efficiency.

2 Fractional OGR based WDM channel allocation

In mathematics, the term "Golomb Ruler"^[8,9] refers to a set of non-negative integers such that no two distinct pairs of numbers from the set have the same difference. An OGR is the shortest Golomb Ruler possible for a given number of marks. Therefore, applying OGR to the channel allocation problem, it was possible to achieve the smallest distinct number to be used for the channel allocation. Since the difference between any two numbers is distinct, the new FWM frequencies generated would not fall into the one already assigned for the carrier channels. However, using OGR was not sufficient as the operating bandwidth would be increased significantly as the existing methods. Therefore, an efficient algorithm has to be designed to allocate the channels so as to restrict the expansion of the bandwidth.

In WDM systems, the slot width must be large enough to avoid appreciable overlap of channel and the FWM spectra, even with some instability in the channel

frequencies. Since the rms frequency jitter for a FWM wave is three times that of a channel, the superimposition of the spectra is negligible when the channel frequency stability is of the order of slot-width/10. This is provided that the slot width is greater than or equal to 2 x bitrate. In order to provide an adequate amount of rejection without distorting the desired channel, a minimum channel separation of greater than or equal to 10 x bitrate should be provided.

In this method, we aim to achieve reduction in FWM effect with the WDM system using the same operating bandwidth as for equally spaced channel allocation. This could be achieved by allocating some channels nearer to other channels. However, with the reduction of frequency spacing between some channels, the interchannel interference (ICI) would be increased. Therefore, this method will attempt to find an optimal point where the distortion caused by both the ICI and FWM will be minimal. Incorporating this algorithm with OGR, a systematic approach to the channel allocation could be achieved whereby no FWM signals fall exactly on the carrier channel and the operating bandwidth would not need to be expanded.

For N channels, the OGR for N marks is used. The first element of all OGRs is 0 and in this method, only the rest of the elements are utilized in the algorithm. The operating bandwidth is split into "Pre-allocate" section and "Post-allocate" section. The "Pre-allocate" bandwidth section is divided by the total number of channels, so as to obtain the initial channel spacing. The "Post-allocate" bandwidth section is then divided into parts determined by the modified OGR vector. The OGR vector is formed by removing the first element of 0. The initial modified OGR vector is formed by rearranging the elements, so that the channel spacing of channels nearer to the center frequency will be wider. Subsequent modified OGR vectors are formed by incrementing each element with an Incrementation Factor. The notion here is that since the difference for any two elements in the OGR is distinct, incrementing each element of the OGR by a same value would still result in distinct difference. The Incrementation Factor will also have an impact on the allocation in that it will be in increasing order of significance from the outer to

the inner elements. After which, a near equally spaced channel allocation situation would be reached following multiple iterations of the algorithm. The performance of the WDM system is then observed for each iteration to locate the allocation where the performance is optimal. This channel allocation set will be used for the WDM system design eventually.

3 Simulation

The 8-channel x 10Gbps, 100GHz spacing for equal channel spacing allocation, WDM system to be simulated in VPI Transmission Maker^[10] was designed. The 200km fiber has an EDFA after each 100km span to compensate for the attenuation loss of 0.2dB/km. The average power of each laser was set to 1mW.

With a pre-allocated bandwidth of 50% and dispersion value of 3ps/nm.km, the algorithm is iterated for 50 rounds. Fig. 1 shows the BER plot for the 8 channels (51 sets of allocation, the first being the equally spaced allocation). Fig. 2 shows the output spectrum for the equally spaced allocation.

The BER improvement factor obtained by $\log(\text{BER}_{\text{Old}}/\text{BER}_{\text{New}})$, shows that allocation set 2 obtained the best average BER improvement factor of 2.09 for the 8 channels. Figure 3 shows the output spectrum for set 2.

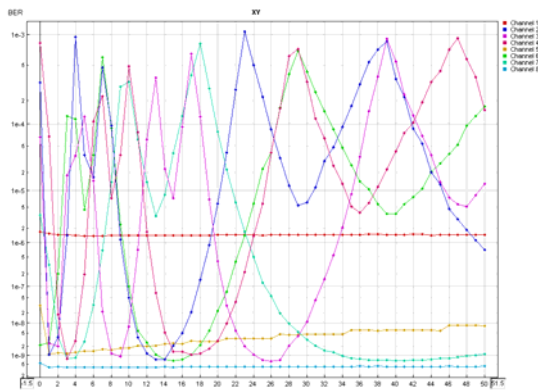


Fig. 1 BER Plot

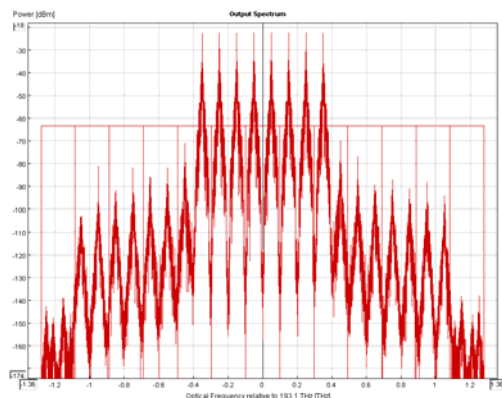


Fig. 2 Output Spectrum for Equally Spaced Allocation

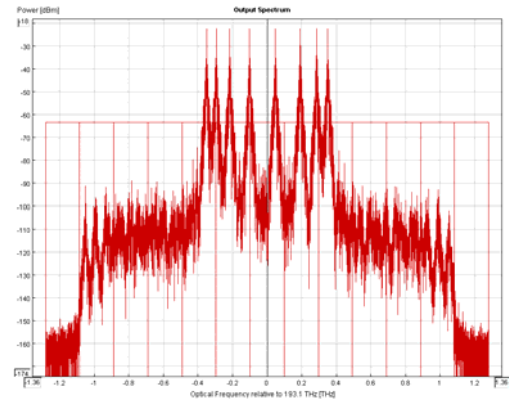


Fig. 3 Output Spectrum for Set 2

Conclusion

It is shown in the simulation that, with a dispersion value of 3ps/nm.km and 50% pre-allocated bandwidth, the average BER Improvement Factor of the 8 channels for the best allocation set is 2.09. In existing optimum unequally spaced channel allocation methods, an eight-channel WDM system requires a 1.6 times expansion of the bandwidth, compared to the equally spaced channel allocation method. However, in this newly proposed method, the bandwidth efficiency is maintained, while the system performance is increased significantly.

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