Saddlepoint Approximation for Calculating Performance of Spectrum-Sliced WDM Systems

by
Seemant Teotia
Dr.Ira Jacobs, Chairman
Electrical Engineering

ABSTRACT

Spectrum slicing is a novel technique for the implementation of wavelength-division multiplexing (WDM). While conventional WDM systems employ laser diodes operating at discrete wavelengths as carriers for the different data channels that are to be multiplexed, spectrum-sliced systems make use of spectral slices of a broadband noise source for the different data channels, thus being economically attractive.

In spectrum-sliced WDM systems with an optical preamplifier receiver there is an optimum $m=B_0T$ (B_0 = optical channel bandwidth, T = bit duration) to minimize the average number of photons-per-bit ($\overline{N}_p$) required at the receiver for a given error probability (P_e). Both the optimum m and the minimum $\overline{N}_p$ increase as interchannel interference increases. This has been analyzed previously by using the Gaussian approximation, or by assuming that the signals at the decision point are chi-square distributed. Although the chi-square distribution is valid in the case where there is no interference, it is not valid in the presence of interference, since the interference from the neighboring channel has a smaller bandwidth than the signal. In this thesis, a different method is used to analyze this problem. This method is called the Saddlepoint Approximation, and while the exact analysis required determination of the probability density function (pdf) of the received signal, the saddlepoint method makes use of moment generating functions (MGFs) which have a much simpler form and don't require the convolution operations the pdfs require.

The saddlepoint method is validated by comparing results obtained with the chi-square analysis for the no interchannel interference case when a rectangular shaped filter is used. The effect of non-rectangular spectra on receiver sensitivity with the use of the Saddlepoint Approximation is also investigated. After verifying its validity, the method is applied to the interchannel interference case caused by filter overlap. It is shown that for small filter overlap, use of an equivalent chi-square distribution is valid, but when the overlap becomes larger, the performance approaches that calculated using the Gaussian distribution. It is shown that there is an optimum filter overlap to maximize the total system throughput when total bandwidth is constrained. Operating at this optimum, the total system throughput is 135 Gbits/s when the total system bandwidth is 4.4 THz (35 nm) for a Bit Error Rate (BER) of 10^{-9}.