<center>**Chapter 4**</center>

Effect of Interchannel Interference on Receiver Performance

In the previous two chapters we have assumed our systems to be ideal without any interchannel interference. In this chapter we analyze the effects of interchannel interference on the performance of the receiver. The model assumed is that of rectangular spectra with spacing of channels less than channel width so that there is some overlap. It is shown that some overlap in the system is acceptable and the performance of the system in terms of throughput for a given total bandwidth improves until an optimum overlap value.

4.1. Mathematical Formulation

4.1.1. Single-Sided Interference

It is assumed in this sub-section that there is only single-sided interchannel interference present in the system. In the next sub-section we will consider interference from both adjacent channels.

Initially, $z(t)$ is assumed to be the received signal. $z(t)$ is a zero mean Gaussian process. This signal has two possibilities:

$1 = $ data signal + noise + interchannel interference

$0 = $ noise + interchannel interference

$z(t)$ can be divided in two parts:

$$z(t) = z_a(t) + z_b(t) \tag{4.1}$$

with $z_a(t)$ having a rectangular bandwidth B_0, and $z_b(t)$ having a rectangular bandwidth kB_0. The parameter k is referred to as the channel overlap parameter, it represents the overlapping percentage of an adjacent channel. It varies between 0 and 1, with 0 corresponding to no overlap and 1 corresponding to complete overlap.

Figure 4.1 illustrates a scenario where one channel is interfering with another. With the aid of this figure we can obtain the mathematical definition of k. In this figure B_0 is the optical bandwidth and f_R is the channel spacing. The overlap width is defined as

$$\text{Overlap Bandwidth} = B_0 - f_R \tag{4.2}$$

As m is defined as the product of the optical bandwidth and the bit period, we can obtain the following expression relating the Optical Bandwidth and the channel overlap parameter:

$$mk = (B_0 - f_R)T \tag{4.3}$$

By isolating k and using the definition of m, we obtain the following mathematical expression for the channel overlap parameter:

$$k = 1 - \frac{f_R}{B_0} \tag{4.4}$$

The energy of the received signal is given by:

$$E = \frac{1}{T}\int_0^T z^2(t)dt = \frac{1}{T}\left(\int_0^T z_a^2(t)dt + \int_0^T z_b^2(t)dt + 2\int_0^T z_a(t)z_b(t)dt\right) \tag{4.5}$$

With the use of the Karhunen-Loeve expansion we can transform the integrals above into series:

$$\frac{1}{T}\int_0^T z_a^2(t)dt = \sum_{i=1}^{m} z_{a_i}^2 + \sum_{i=1}^{km} z_{b_i}^2 \qquad (4.6)$$

To expand the third element of (4.5), we need to define $z_a(t)$ and $z_b(t)$ as:

$$z_a(t) = \sum_{i=1}^{m} z_{a_i} \varphi_i(t) \qquad (4.7)$$

$$z_b(t) = \sum_{j=1}^{km} z_{b_j} \varphi_j(t) \qquad (4.8)$$

where $\varphi_i(t)$ and $\varphi_j(t)$ are the eigenfunctions of components a an b. For rectangular spectra it may be assumed that there are a finite number (equal to the time bandwidth product) of non-zero eigenvalues all of which are equal [18].

Thus the third element of (4.5) becomes

$$2\int_0^T z_a(t)z_b(t)dt = 2\sum_{i=1}^{m}\sum_{j=1}^{km} z_{a_i} z_{b_j} \int \varphi_i \varphi_j dt = 2\sum_{j=1}^{km} z_{a_j} z_{b_j} \qquad (4.9)$$

The energy of the received signal then assumes the following form:

$$E = \sum_{i=1}^{m} z_{a_i}^2 + \sum_{i=1}^{km} z_{b_i}^2 + 2\sum_{i=1}^{km} (z_{a_i})(z_{b_i}) \qquad (4.10)$$

The above equation can be simplified into:

$$E = \sum_{i=1}^{km} (z_{a_i} + z_{b_i})^2 + \sum_{i=km+1}^{m} z_{a_i}^2 \qquad (4.11)$$

It should be noted once again that the Karhunen-Loeve expansion has an infinite number of terms. However, replacement by a finite sum of terms, all of which have the

same variance, is a good approximation for the rectangular spectra case as indicated previously in Chapter 3.

The first element of (4.11) represents signal, noise and interference, and the second element represents signal and noise. The equation is valid for both the ON and OFF cases. For the OFF-case it should be noted again that the data signal will be absent.

The moment generating function of the received signal $z(t)$ in the ON state can be represented as:

$$M_{ON}(s) = \left[1 - 2\left(\sigma_s^2 + \sigma_n^2 + \sigma_i^2\right)2mks\right]^{-2mk}\left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)2m(1-k)s\right]^{-2m(1-k)} \quad (4.12)$$

As the variance of the interfering signal is the same as of the transmitted signal, we have

$$M_{ON}(s) = \left[1 - 2\left(2\sigma_s^2 + \sigma_n^2\right)2mks\right]^{-2mk}\left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)2m(1-k)s\right]^{-2m(1-k)} \quad (4.13)$$

By normalizing the equation above we get:

$$M_{ON}(s) = \left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)ks\right]^{-2mk}\left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)(1-k)s\right]^{-2m(1-k)} \quad (4.14)$$

For the OFF case the MGF is obtained in a similar fashion and is given by

$$M_{OFF}(s) = \left[1 - 2\left(\sigma_i^2 + \sigma_n^2\right)2mks\right]^{-2mk}\left[1 - 2\sigma_n^2 2m(1-k)s\right]^{-2m(1-k)} \quad (4.15)$$

Substituting σ_i^2 by σ_s^2, and then normalizing, we get:

$$M_{OFF}(s) = \left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)ks\right]^{-2mk}\left[1 - 2\sigma_n^2 2m(1-k)s\right]^{-2m(1-k)} \quad (4.16)$$

4.1.2. Double-Sided Interference

Single-sided interchannel interference is only valid for a system which has two channels or for the extreme channels of a system. Thus, for practical systems we have to consider the effect of the interference of both adjacent channels.

The difference from the single-sided case is that instead of including only one interfering signal in our calculations, we have to include now two, both having the same variance. The calculations to obtain the energy of the received signal are done in the same manner they were done in the previous sub-section. Thus, the MGF of the received signal in the ON-state is given by

$$M_{ON}(s) = \left[1 - 2\left(\sigma_s^2 + \sigma_n^2 + 2\sigma_i^2\right)2mks\right]^{-2mk} \left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)2m(1-k)s\right]^{-2m(1-k)} \quad (4.17)$$

As the variances of the interfering signals are the same as of the transmitted signal, we have

$$M_{ON}(s) = \left[1 - 2\left(3\sigma_s^2 + \sigma_n^2\right)2mks\right]^{-2mk} \left[1 - 2\left(\sigma_s^2 + \sigma_n^2\right)2m(1-k)s\right]^{-2m(1-k)} \quad (4.18)$$

In a similar manner, the MGF for the OFF-state is obtain as

$$M_{OFF}(s) = \left[1 - 2\left(2\sigma_i^2 + \sigma_n^2\right)2mks\right]^{-2mk} \left[1 - 2\sigma_n^2 2m(1-k)s\right]^{-2m(1-k)} \quad (4.19)$$

which can be transformed into

$$M_{OFF}(s) = \left[1 - 2\left(2\sigma_s^2 + \sigma_n^2\right)2mks\right]^{-2mk} \left[1 - 2\sigma_n^2 2m(1-k)s\right]^{-2m(1-k)} \quad (4.20)$$

4.2. Evaluation of Interchannel Interference

Three different methods were used to evaluate the receiver performance with the inclusion of the interchannel interference: 1) The Saddlepoint Approximation; 2) The

Gaussian Approximation; and 3) The Chi-Square Approximation. Each of these methods is described next. We initially use these methods for the single-sided interference case for purposes of illustration and then extend these results for the double-sided interference case.

4.2.1. Saddlepoint Approximation

The MGF for the ON state is given by equation (4.14). By using (2.9) and (2.10) which were derived in Chapter 2, we get the MGF as:

$$M_{ON}(s) = \left[1 - 2\left(\frac{2}{x} + 1\right)ks\right]^{-2mk} \left[1 - 2\left(\frac{1}{x} + 1\right)(1-k)s\right]^{-2m(1-k)} \tag{4.21}$$

By using the following auxiliary variables:

$$
\begin{aligned}
n_1 &= -2mk \\
n_2 &= -2m(1-k) \\
\lambda_1 &= 2\left(\frac{2}{x} + 1\right)k \\
\lambda_2 &= 2\left(\frac{1}{x} + 1\right)(1-k)
\end{aligned}
$$

we obtain

$$M_{ON}(s) = (1 - \lambda_1 s)^{n_1} (1 - \lambda_2 s)^{n_2} \tag{4.22}$$

To apply the saddlepoint approximation, we have to use the 'phase' function $\phi_{ON}(s)$ [22], which is described in Appendix A and is given by (A.8). Here, its normalized version is given by

$$\phi_{ON}(s) = \ln\left\{(1 - \lambda_1 s)^{n_1} (1 - \lambda_2 s)^{n_2}\right\} - s\alpha - \ln|s| \tag{4.23}$$

The first derivative of (4.23) is given by

$$\phi'_{ON}(s) = -\frac{1}{s} - \alpha - \frac{n_1 \lambda_1}{1 - \lambda_1 s} - \frac{n_2 \lambda_2}{1 - \lambda_2 s} \tag{4.24}$$

And the second derivative is given by

$$\phi''_{ON}(s) = \frac{1}{s^2} - \frac{n_1 \lambda_1^2}{(1 - \lambda_1 s)^2} - \frac{n_2 \lambda_2^2}{(1 - \lambda_2 s)^2} \tag{4.25}$$

When applying the saddlepoint approximation, the roots of $\phi'_{ON}(s)$ are needed. Solving for the roots we obtain a third-order polynomial equation of the type

$$a_{ON} s^3 + b_{ON} s^2 + c_{ON} s + d_{ON} = 0 \tag{4.26}$$

where

$$a_{ON} = -\alpha \lambda_1 \lambda_2$$
$$b_{ON} = \lambda_1 \lambda_2 (-1 + n_1 + n_2) + \alpha(\lambda_1 + \lambda_2)$$
$$c_{ON} = \lambda_1 (1 - n_1) + \lambda_2 (1 - n_2) - \alpha$$
$$d_{ON} = -1$$

Equation (4.26) has three roots, two positives and one negative. In order to calculate the BER, the negative root is taken. The reason why the negative root is taken is that this root minimizes [23] the 'phase' function given by (4.23) as verified by evaluating the second derivative.

In a similar fashion to the ON-case, we can obtain the MGF for OFF-case as

$$M_{OFF}(s) = \left[1 - 2\left(\frac{1}{x} + 1\right)ks\right]^{-2mk} \left[1 - 2(1 - k)s\right]^{-2m(1-k)} \tag{4.27}$$

By using the following auxiliary variables

$$n_1 = -2mk$$
$$n_2 = -2m(1-k)$$
$$\lambda_3 = 2\left(\frac{1}{x}+1\right)k$$
$$\lambda_4 = 2(1-k)$$

we get the normalized 'phase' function $\phi_{OFF}(s)$ as

$$\phi_{OFF}(s) = \ln\left\{(1-\lambda_3 s)^{n_1}(1-\lambda_4 s)^{n_2}\right\} - s\alpha - \ln|s| \qquad (4.28)$$

The first derivative of (4.28) is given by

$$\phi'_{OFF}(s) = -\frac{1}{s} - \alpha - \frac{n_1\lambda_3}{1-\lambda_3 s} - \frac{n_2\lambda_4}{1-\lambda_4 s} \qquad (4.29)$$

And the second derivative is

$$\phi''_{OFF}(s) = \frac{1}{s^2} - \frac{n_1\lambda_3^2}{(1-\lambda_3 s)^2} - \frac{n_2\lambda_4^2}{(1-\lambda_4 s)^2} \qquad (4.30)$$

When calculating the roots of $\phi'_{OFF}(s)$ we obtain the following polynomial equation

$$a_{OFF}s^3 + b_{OFF}s^2 + c_{OFF}s + d_{OFF} = 0 \qquad (4.31)$$

where

$$a_{OFF} = -\alpha\lambda_3\lambda_4$$
$$b_{OFF} = \lambda_3\lambda_4(-1 + n_1 + n_2) + \alpha(\lambda_3 + \lambda_4)$$
$$c_{OFF} = \lambda_3(1 - n_1) + \lambda_4(1 - n_2) - \alpha$$
$$d_{OFF} = -1$$

This polynomial also has two positive roots and one negative root. The larger positive root is taken in order to calculate the BER as it minimizes the 'phase' function (4.28).

For fixed BERs of 10^{-6} and 10^{-9}, the optimum values of m and the receiver sensitivity $\overline{N}_p$ were calculated for different values of the channel overlap k. The results are shown in Figures 4.2 and 4.3.

As it can be seen from the figures, as expected the receiver sensitivity degrades as the channel overlap increases. However, there is a performance improvement independent of the BER when the channel overlap becomes greater than 80%. This slight improvement might be a result of the reduced fluctuation of the interference compensating for the increased interference.

In a similar manner, the saddlepoint approximation was used for the double-sided interference case. It should be noted here that channel overlap only up to 0.5 was considered, due to the fact that with an overlap of 0.5 there would be complete overlap, 50% overlap from each adjacent channel. The results are shown in Figures 4.4 and 4.5. As it can be seen interchannel interference degrades receiver performance more aggressively in the double-sided interference case.

4.2.2. Gaussian Approximation

The second method used to evaluate the effect of interchannel interference on the receiver performance is the Gaussian Approximation. This method has already been described and used for the case of no interchannel interference ($k = 0$) in Chapter 2.

The MGF for the ON-case is given by (4.12). To use the Gaussian Approximation the first and second derivatives of the MGF have to be calculated in order to obtain the mean and standard deviation.

Thus, we have:

$$M'_{ON}(s) = n_1\lambda_1\left(1+\lambda_1 s\right)^{n_1-1}\left(1+\lambda_2 s\right)^{n_2} + n_2\lambda_2\left(1+\lambda_2 s\right)^{n_2-1}\left(1+\lambda_1 s\right)^{n_1} \qquad (4.32)$$

and

$$M''_{ON}(s) = n_1\left(n_1-1\right)\lambda_1^2\left(1+\lambda_1 s\right)^{n_1-2}\left(1+\lambda_2 s\right) + n_2\left(n_2-1\right)\lambda_2^2\left(1+\lambda_2 s\right)^{n_2-2}\left(1+\lambda_1 s\right) +$$
$$+ 2n_1 n_2\lambda_1\lambda_2\left(1+\lambda_1 s\right)^{n_1-1}\left(1+\lambda_2 s\right)^{n_2-1} \qquad (4.33)$$

As the mean is given by $M'_{ON}(0)$ we have

$$\mu_{ON} = n_1\lambda_1 + n_2\lambda_2 \qquad (4.34)$$

The variance which is given by (2.34) is

$$\sigma_{ON}^2 = -n_1\lambda_1^2 - n_2\lambda_2^2 \qquad (4.35)$$

By replacing $n_1, n_2, \lambda_1,$ and λ_2 with their definitions the following equations for the mean and standard deviation are obtained for the ON-case:

$$\mu_{ON} = 4mk^2\left(\frac{2}{x}+1\right) + 4m(1-k)^2\left(\frac{1}{x}+1\right) \qquad (4.36)$$

and

$$\sigma_{ON} = \sqrt{8mk^3\left(\frac{2}{x}+1\right)^2 + 8m(1-k)^3\left(\frac{1}{x}+1\right)^2} \qquad (4.37)$$

By taking a similar approach in the OFF-case, the mean and standard deviation are obtained as

$$\mu_{OFF} = 4mk^2\left(\frac{1}{x}+1\right) + 4m(1-k)^2 \qquad (4.38)$$

and

$$\sigma_{OFF} = \sqrt{8mk^3\left(\frac{1}{x}+1\right)^2 + 8m(1-k)^3} \qquad (4.39)$$

With the use of the parameters calculated above, the BER can be calculated according to equations (2.27) and (2.28). To analyze the receiver performance the BER was fixed at 10^{-6} and 10^{-9}. The optimum values of m and the receiver sensitivity $\overline{N}_p$ were calculated for different values of the channel overlap k. These results are shown in Figures 4.6 and 4.7.

For the double-sided interference case the procedure is the same. However, equations (4.36) to (4.39) have to be changed to include the effects of two interfering signals and not just one. The equivalent equations are given by

$$\mu_{ON} = 4mk^2\left(\frac{3}{x}+1\right) + 4m(1-k)^2\left(\frac{1}{x}+1\right) \qquad (4.40)$$

$$\sigma_{ON} = \sqrt{8mk^3\left(\frac{3}{x}+1\right)^2 + 8m(1-k)^3\left(\frac{1}{x}+1\right)^2} \qquad (4.41)$$

$$\mu_{OFF} = 4mk^2\left(\frac{2}{x}+1\right) + 4m(1-k)^2 \qquad (4.42)$$

$$\sigma_{OFF} = \sqrt{8mk^3\left(\frac{2}{x}+1\right)^2 + 8m(1-k)^3} \qquad (4.43)$$

The results obtained with the Gaussian Approximation for the double-sided interference case are shown in Figures 4.8 and 4.9.

4.2.3. Chi-Square Approximation

The third and final method used to evaluate the effect of the interchannel interference on the receiver performance is the chi-square approximation. The mean and

variances, which were obtained in the previous section for the Gaussian Approximation, were fitted into the MGF of a random variable with chi-square distribution. After obtaining these new MGFs, the saddlepoint approximation was used to evaluate the receiver performance. It should be noted that this case is similar to the analysis in [28] by Arya and Jacobs with the difference being that while the Saddlepoint Approximation is used here, Arya and Jacobs calculated the exact integrals. The agreement between the Saddlepoint Approximation and the exact analysis has already been shown in Chapter 2.

For the ON-case, the MGF is of the following form

$$M_{ON}(s) = \left[1 - 2\sigma_{ON}^2 s\right]^{-2m_1} \tag{4.44}$$

where

$$m_1 = \frac{\mu_{ON}^2}{2\sigma_{ON}^2} \tag{4.45}$$

μ_{ON} and σ_{ON}^2 are given by (4.36) and (4.37) respectively.

For the OFF-case, the MGF is of the form

$$M_{OFF}(s) = \left[1 - 2\sigma_{OFF}^2 s\right]^{-2m_0} \tag{4.46}$$

where

$$m_0 = \frac{\mu_{OFF}^2}{2\sigma_{OFF}^2} \tag{4.47}$$

and μ_{OFF} and σ_{OFF}^2 are given be equations (4.38) and (4.39) respectively.

The procedure described above is valid for both the single and double-sided interference cases. The only difference is the use of the different values of $\mu_{ON}, \sigma_{ON}^2, \mu_{OFF},$ and σ_{OFF}^2 for each case.

After obtaining these MGFs, the saddlepoint approximation was applied to obtain an expression for the BER. For fixed BERs of 10^{-6} and 10^{-9} the optimum values of m and $\overline{N}_p$ were calculated for different values of k. These results are shown in Figures 4.10 to 4.13. As it can be seen there are slight variations in the slope of the curves for small values of k. This can be explained as follows: in the region where k is relatively small (for both single and double-sided interference cases), the curve is relatively flat, thus small inaccuracies of the saddlepoint approximation can lead to these slope variations.

Figures 4.14 to 4.19 compare the results obtained with all the three methods described for BERs of 10^{-6} and 10^{-9}. By analyzing these figures one important conclusion can be made, when the interchannel interference is low, i.e., small filter overlap, the results obtained with the Chi-Square Approximation are valid. However, when channel overlap becomes large, the Chi-Square Approximation gives results that are too optimistic and **the performance approaches that calculated using the Gaussian Approximation.** This is valid for both the single-sided and double-sided interference cases. Another point to notice is that as expected double-sided interchannel interference degrades the system performance much more aggressively when compared to single-sided interchannel interference.

In the next section it will be shown how interchannel interference affects the transmission capacity of the system, and that it is possible to operate the system while having some interchannel interference.

4.3. Tranmission Capacity

With the results obtained in section 4.2 regarding the effect of interchannel interference on the values of m and Np, two important questions can be answered: How does interchannel interference affect the total system transmission capacity and is it desirable to operate the system with a certain amount of interchannel interference?

The total transmission capacity depends on the total available bandwidth, the optimum value of m, and the channel overlap parameter. First, the definition of m has to be considered [28]:

$$m = B_o T = \frac{B_0}{R_b} \qquad (4.48)$$

where B_0 is the optical bandwidth and R_b is the bit rate per channel.

The total number of channels available in the system is

$$\#channels = \frac{B_c}{f_R} \qquad (4.49)$$

with B_c being the total available bandwidth and f_R the channel spacing.

By using the definition of the channel overlap parameter given by equation (4.4), the following expression can be obtained for channel spacing:

$$f_R = (1-k)B_0 \qquad (4.50)$$

Substituting (4.50) and (4.48) into (4.49), the number of channels is obtained as a function of channel overlap:

$$\#channels = \frac{B_c}{(1-k)B_0} = \frac{B_c}{R_b m(1-k)} \qquad (4.51)$$

As the transmission capacity is the product of the number of channels and the bit rate per channel, the transmission capacity can be expressed as

$$T_{cap} = \frac{B_c}{m(1-k)} \qquad (4.52)$$

For a total bandwidth of 35 nm (4.4 THz), the effect of interchannel interference on the transmission capacity was evaluated when the system operated at the optimum m. All three methods, the Saddlepoint Approximation, the Gaussian Approximation, and the Chi-Square Approximation were used for fixed BERs of 10^{-6} and 10^{-9}. We only evaluated

the transmission capacity for the double-sided interference case as that is the one which represents more closely a practical system. It would not have made sense if we had evaluated the transmission capacity of a system with single-sided interference as that system would only have two channels, which is not a realistic situation.

The results obtained are shown in Figures 4.20 and 4.21. As it can be seen the Gaussian Approximation gives pessimistic results while the Chi-Square Approximation gives results which are too optimistic. With the Saddlepoint Approximation for a BER of 10^{-9}, the maximum transmission capacity is approximately 135 Gb/s. For a BER of 10^{-6} the maximum transmission capacity is approximately 220 Gb/s. Although, a higher BER gives better results, a BER of 10^{-6} would not be acceptable in a system where a lot of data is transmitted. Another point to notice in these results is that there is a slight improvement in the transmission capacity when there is approximately 5% interchannel interference, this is clearly shown when the Saddlepoint Approximation is applied. This is due to the fact that more channels can be put inside the total available bandwidth when there is the influence of interchannel interference, and 5% is the optimum point for the tradeoff between the number of channels added and system performance.
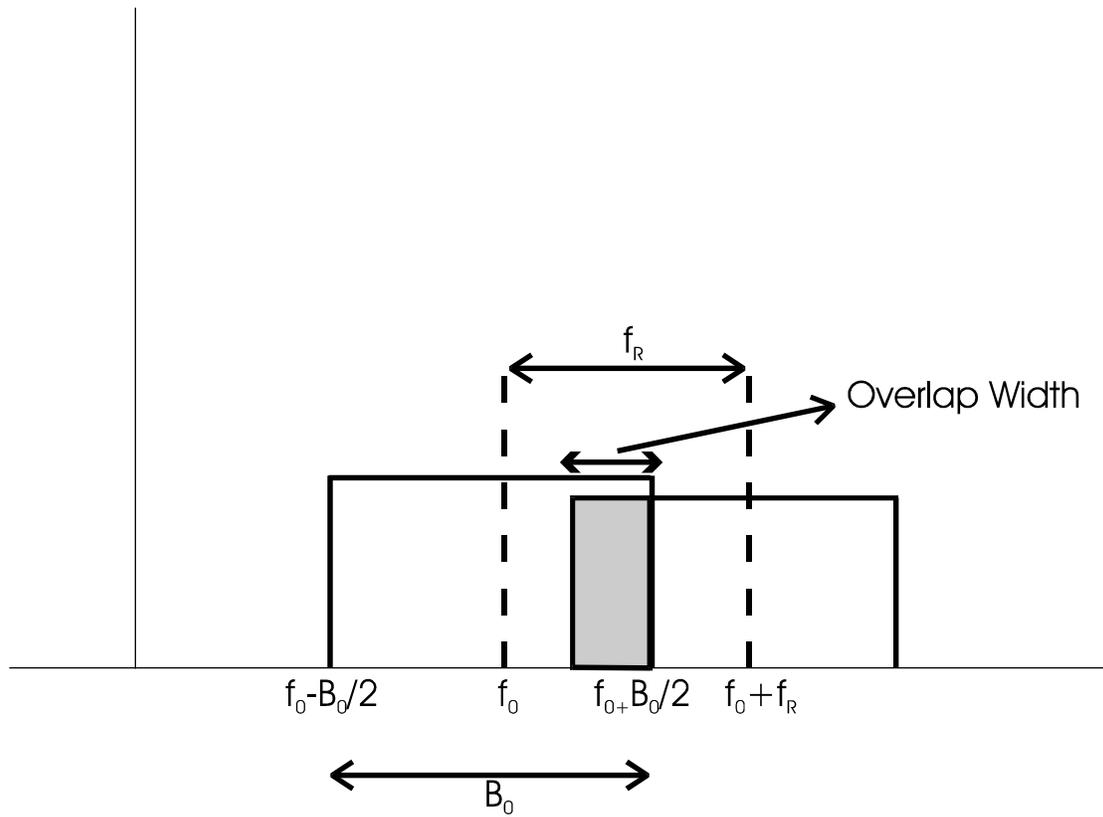
Fig 4.1 *Illustration of interchannel interference.*
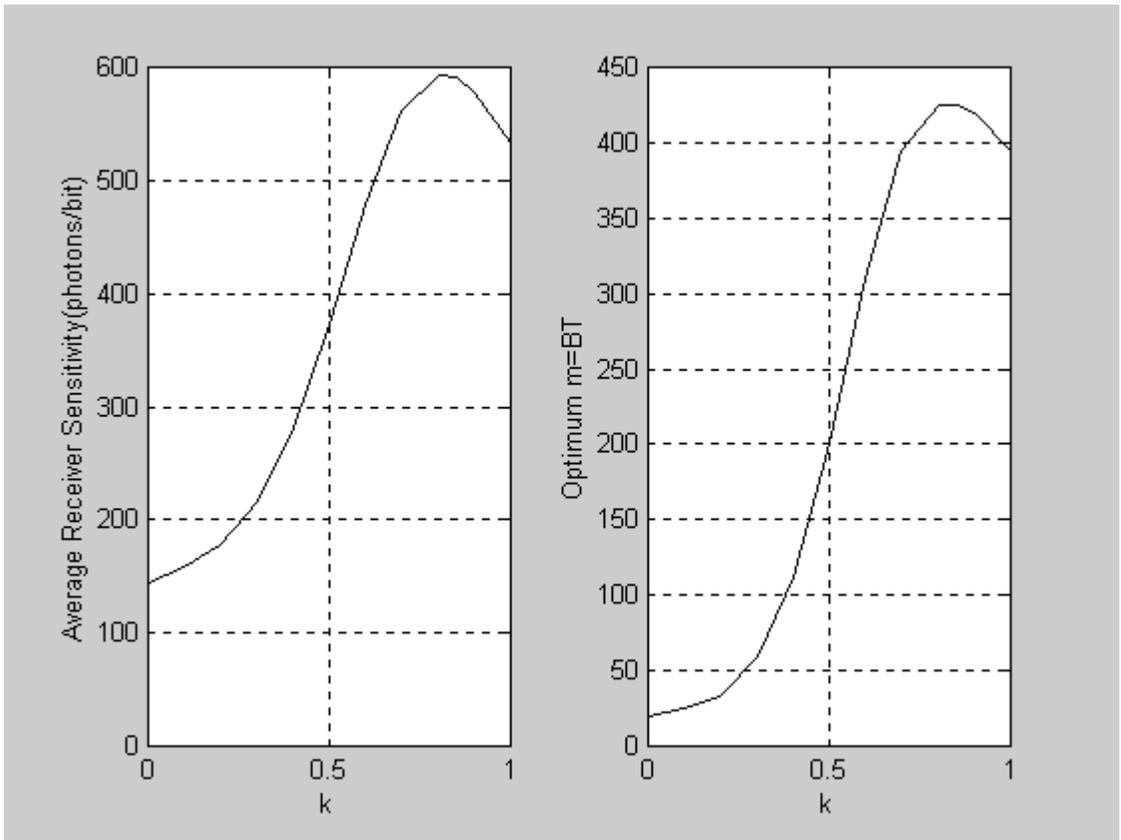
Fig 4.2 *Influence of single-sided interchannel interference on Np and m for Pe=10⁻⁶ when calculated using the Saddlepoint Approximation*
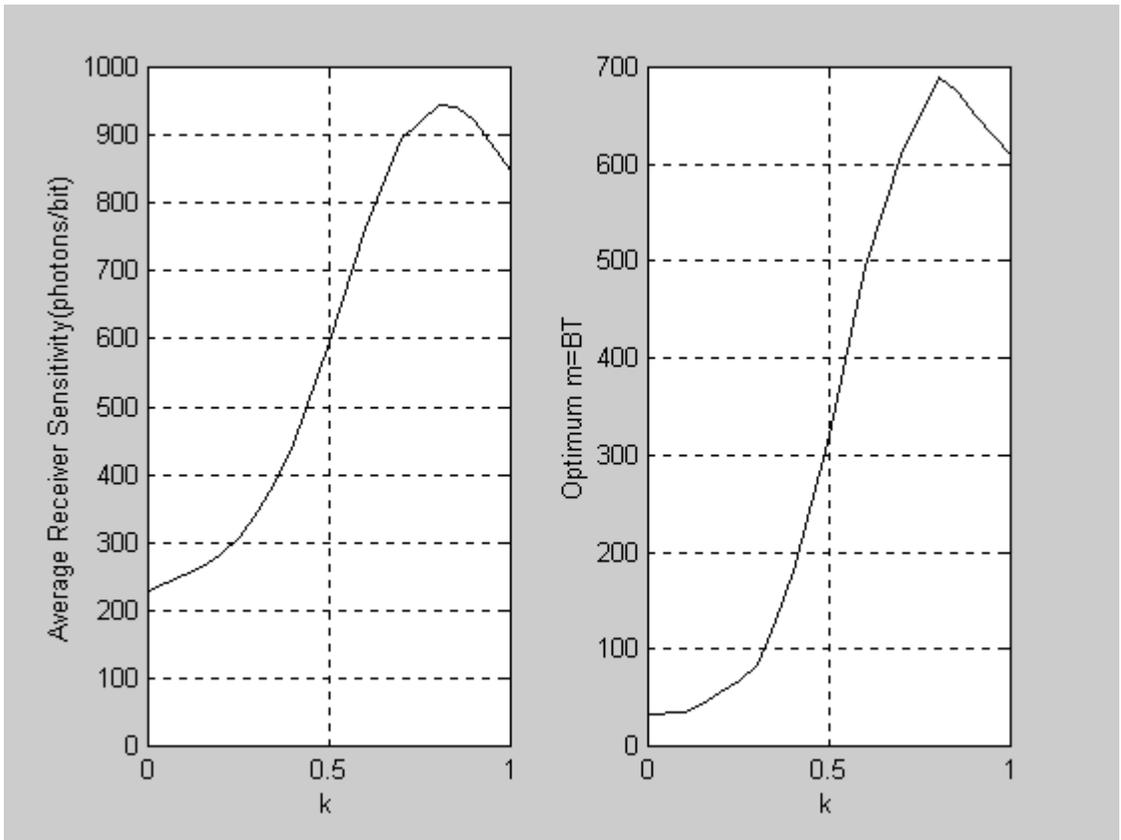
Fig 4.3 *Influence of single-sided interchannel interference on Np and m for Pe=10^{-9} when calculated using the Saddlepoint Approximation*
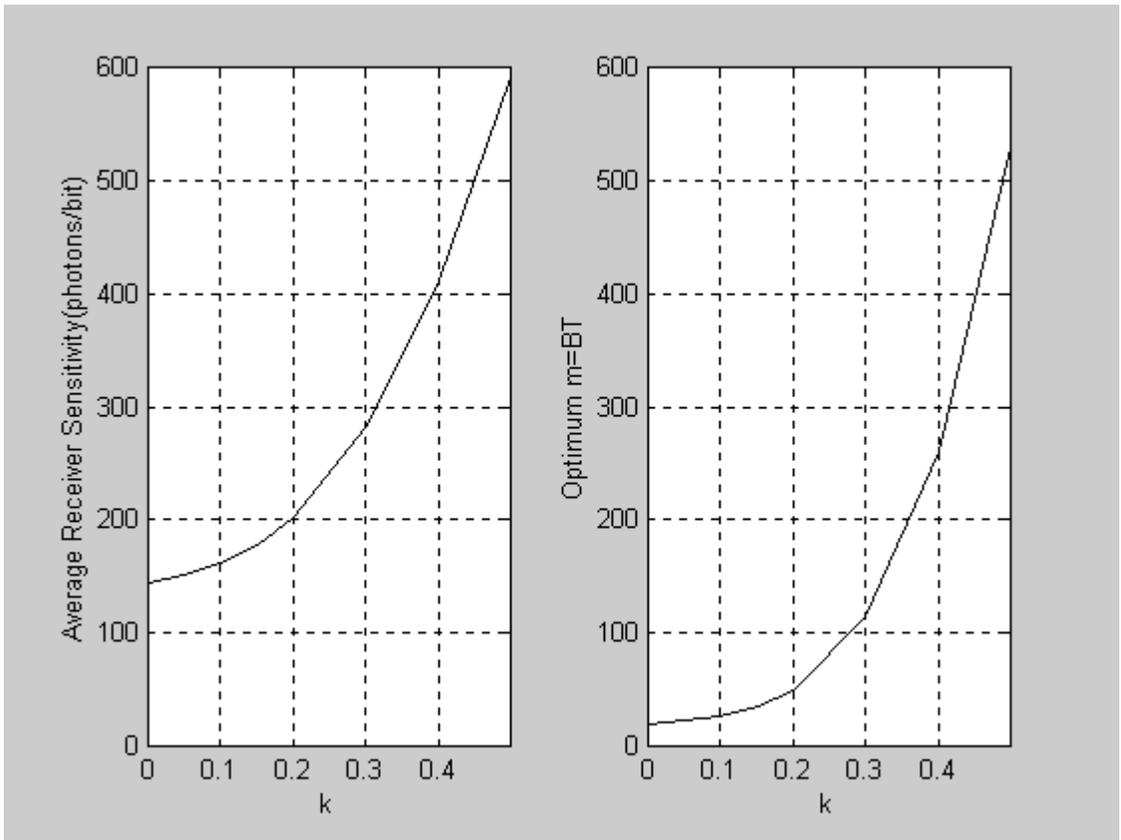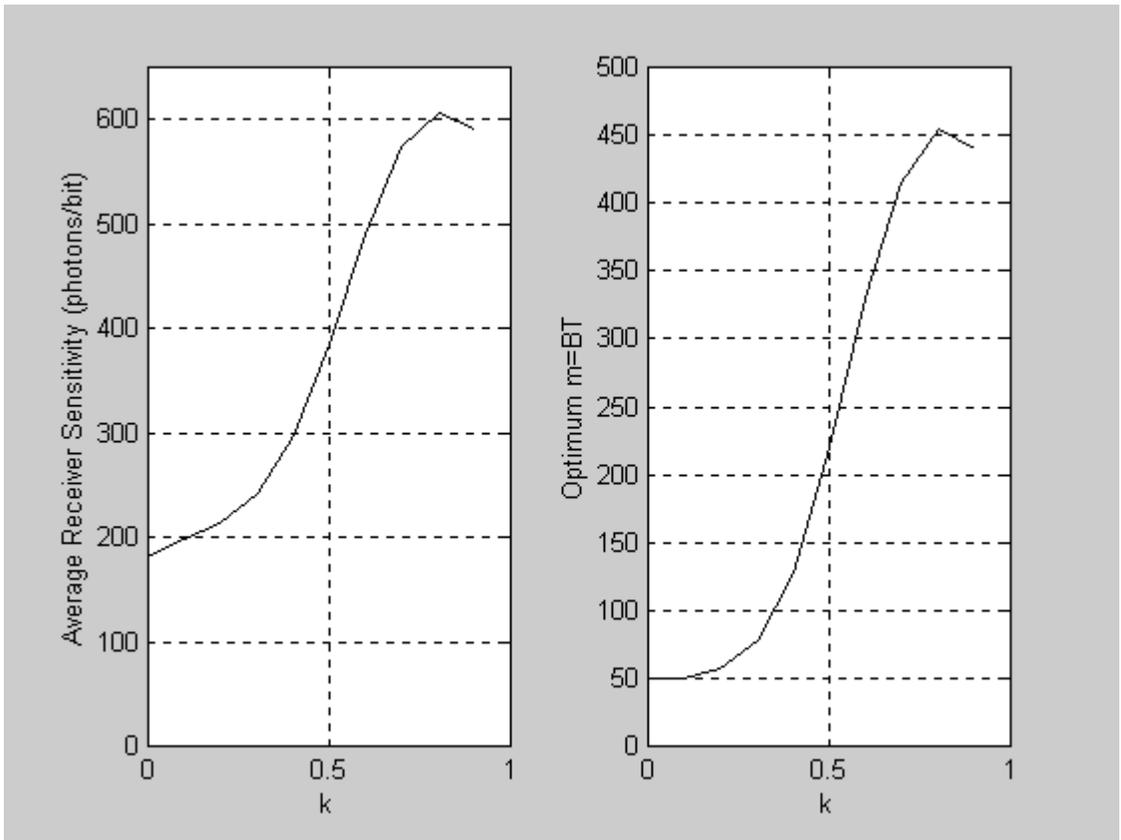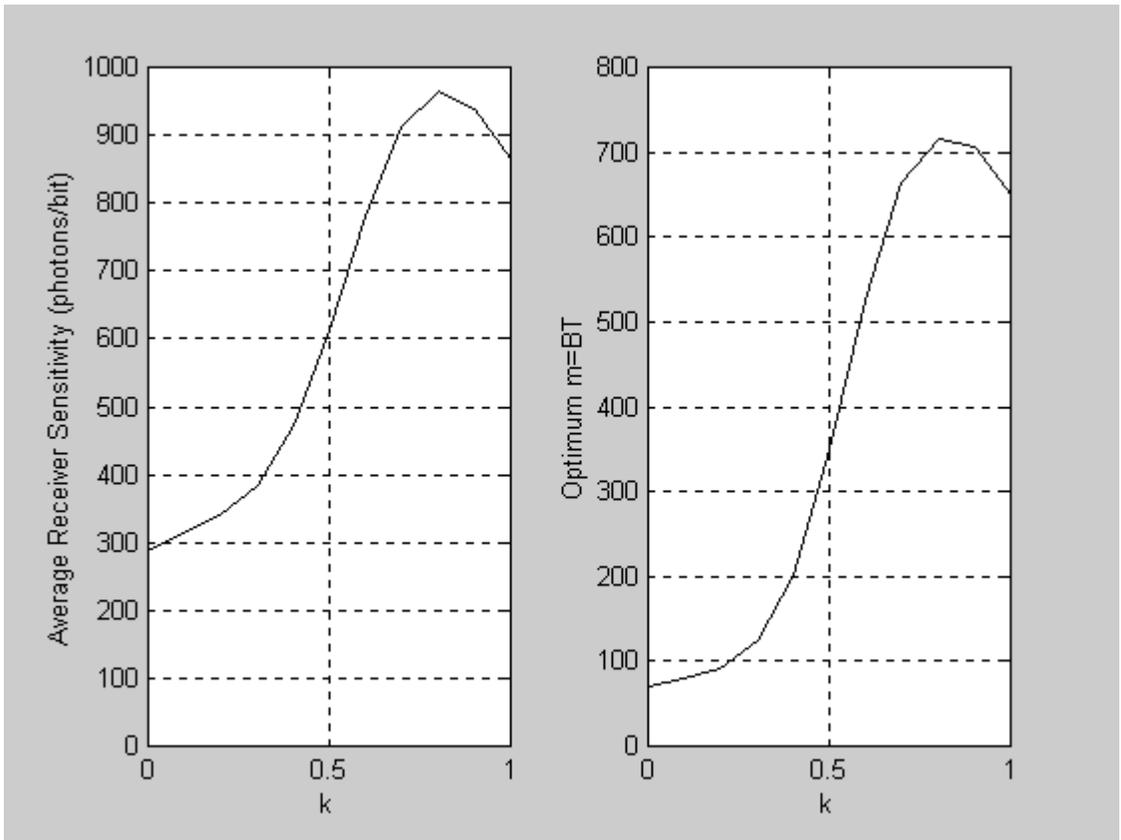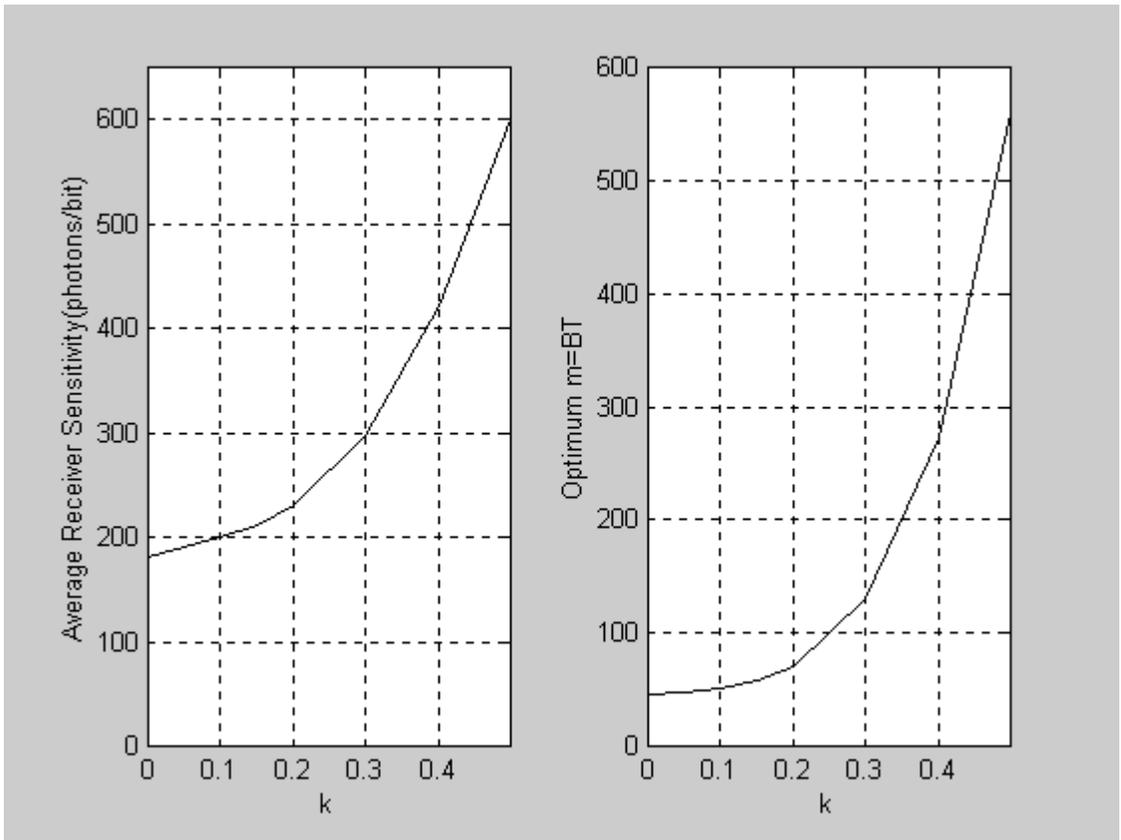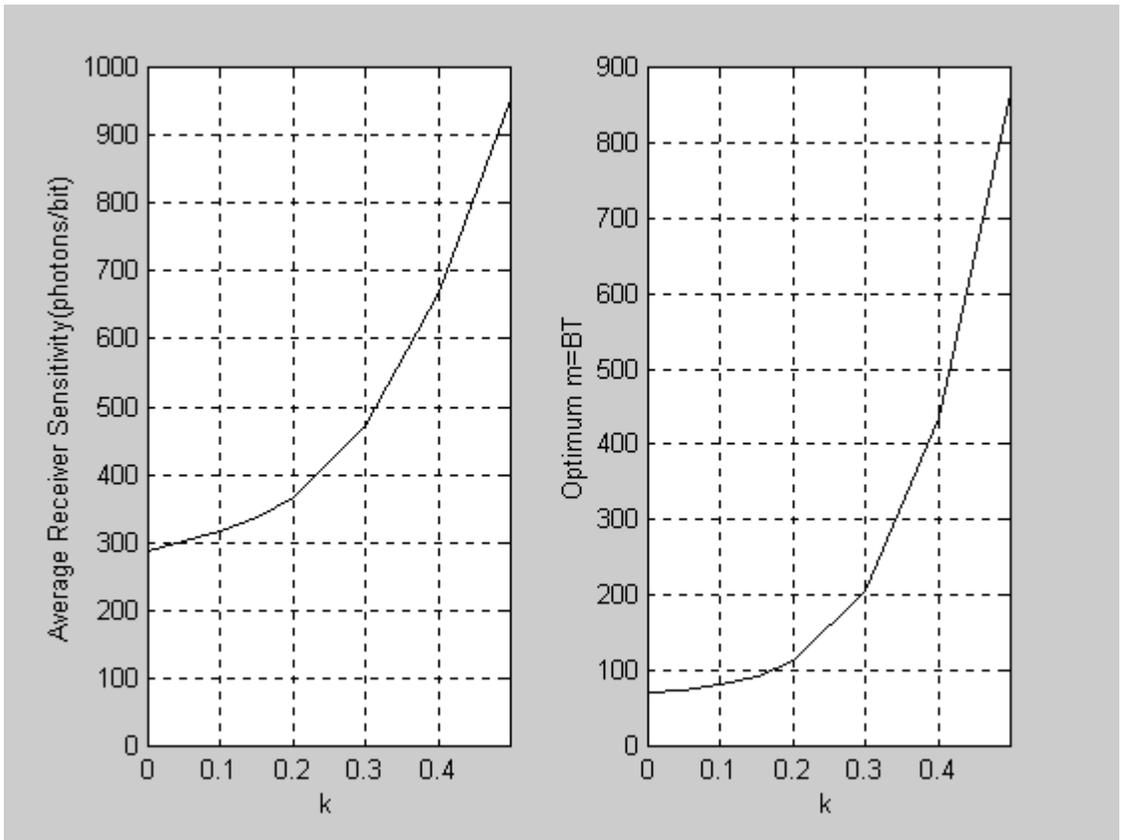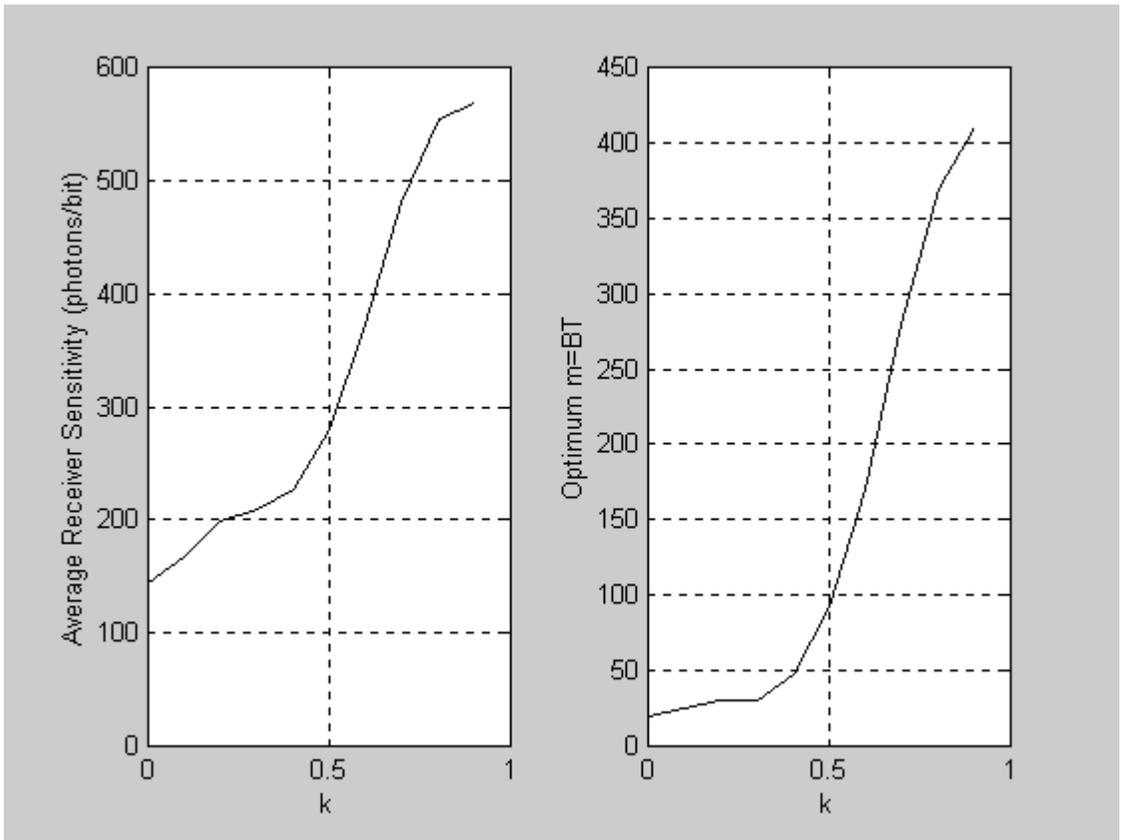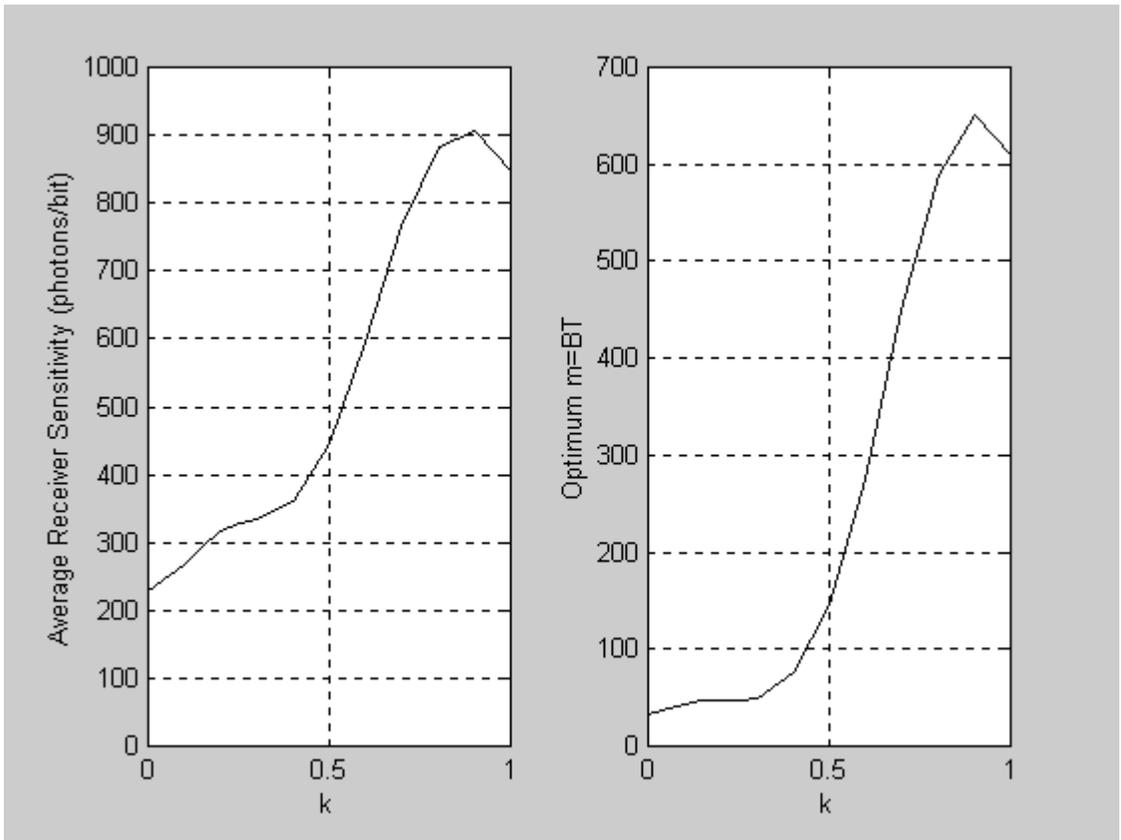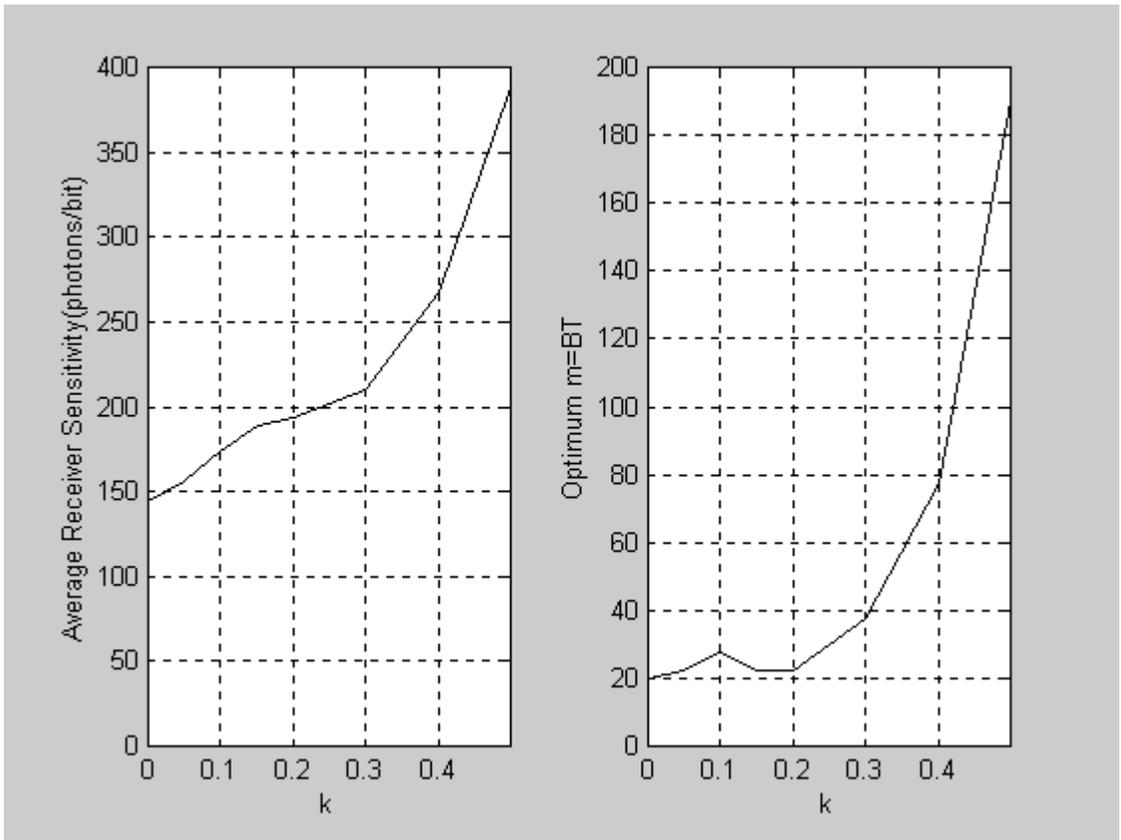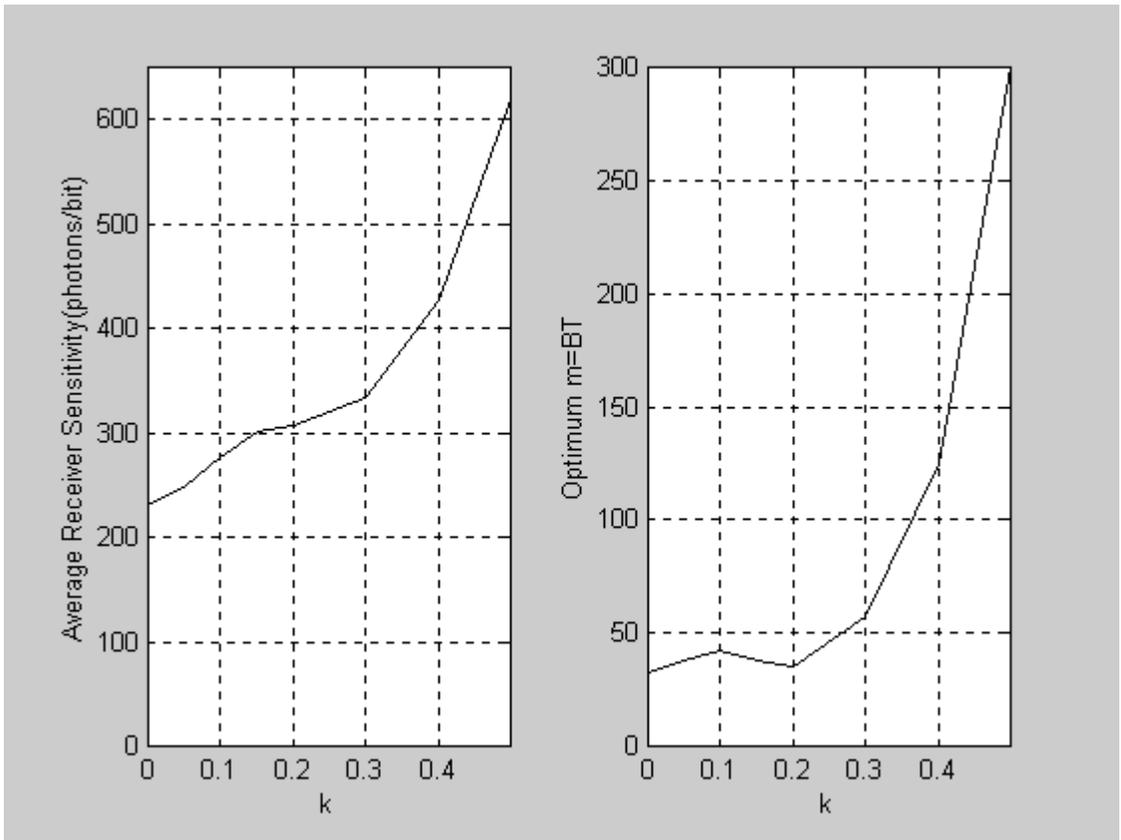
Fig 4.4 *Influence of double-sided interchannel interference on Np and m for Pe=10^{-6} when calculated using the Saddlepoint Approximation*
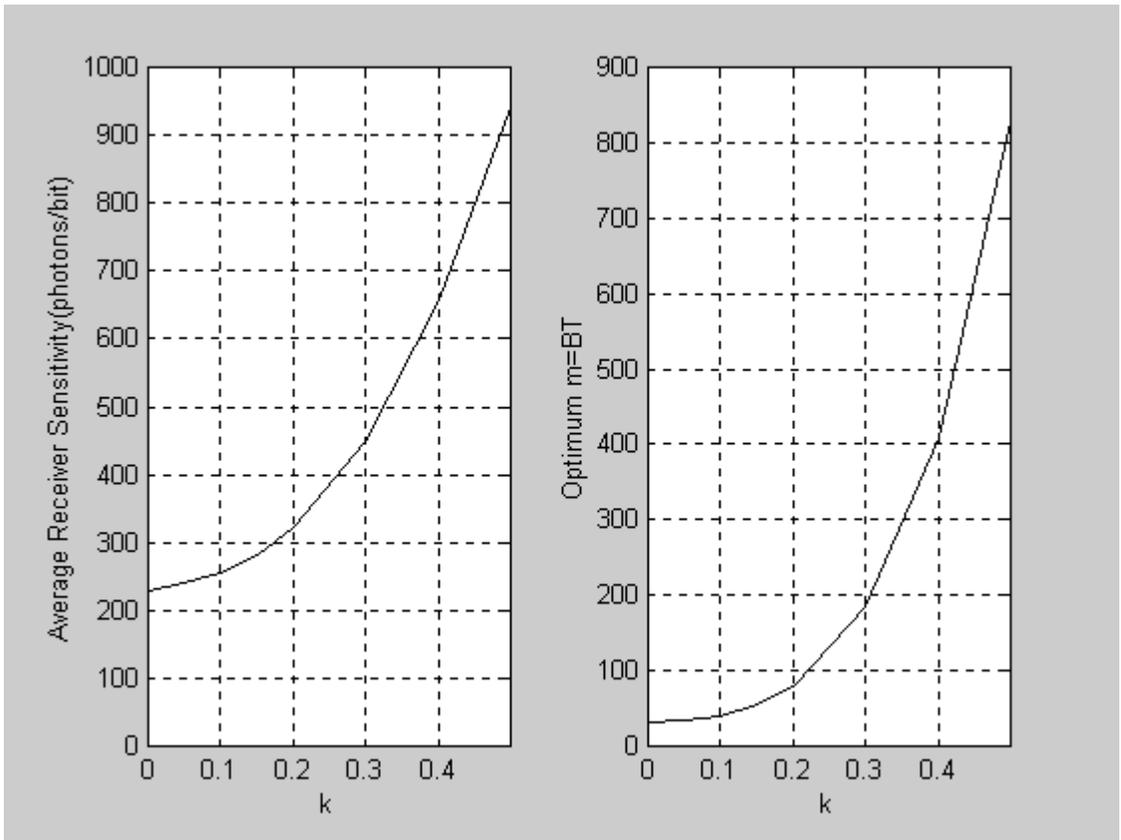
Fig 4.5 *Influence of double-sided interchannel interference on Np and m for Pe=10^{-9}*
when calculated using the Saddlepoint Approximation

Fig 4.6 *Influence of single-sided interchannel interference on Np and m for Pe=10^{-6} when calculated using the Gaussian Approximation*

Fig 4.7 *Influence of single-sided interchannel interference on Np and m for Pe=10^{-9} when calculated using the Gaussian Approximation*

Fig 4.8 *Influence of double-sided interchannel interference on Np and m for Pe=10^{-6} when calculated using the Gaussian Approximation*

Fig 4.9 *Influence of double-sided interchannel interference on Np and m for Pe=10^{-9} when calculated using the Gaussian Approximation*

Fig 4.10 *Influence of single-sided interchannel interference on Np and m for Pe=10^{-6} when calculated using the Chi-Square Approximation*
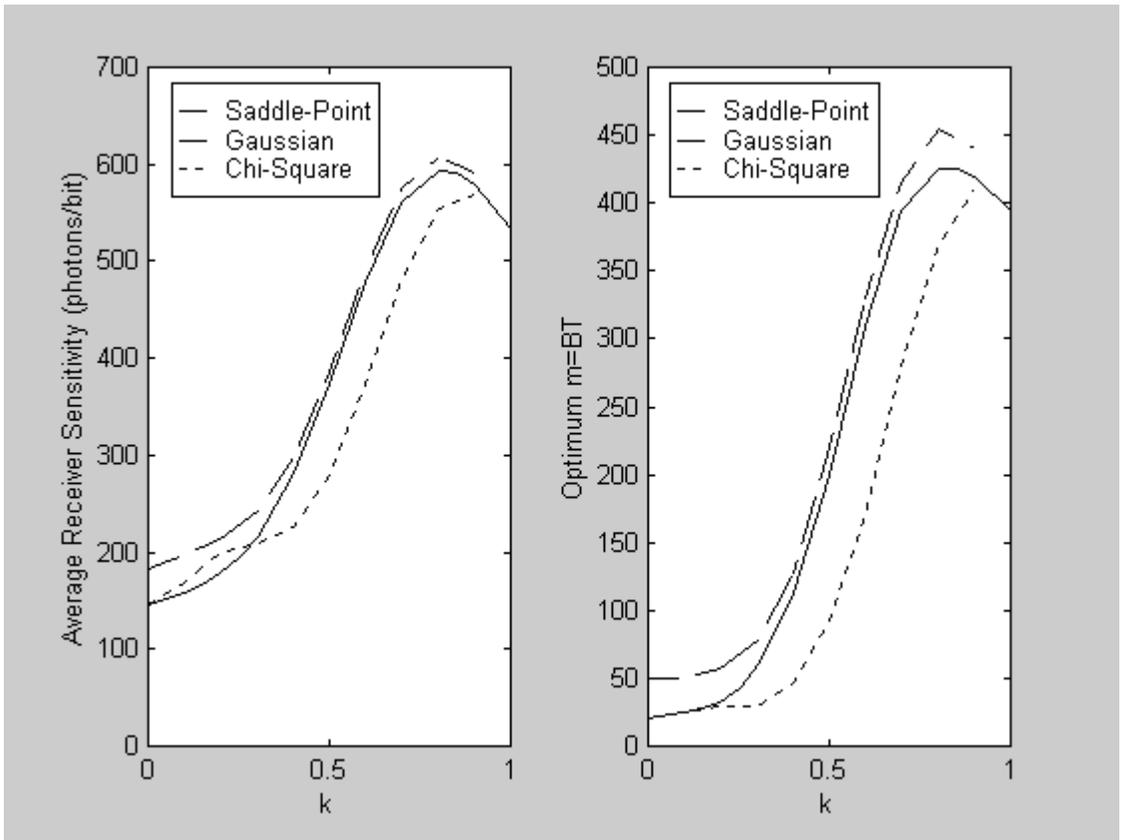
Fig 4.11 *Influence of single-sided interchannel interference on Np and m for Pe=10^{-9} when calculated using the Chi-Square Approximation*

Fig 4.12 *Influence of double-sided interchannel interference on Np and m for Pe=10⁻⁶ when calculated using the Chi-Square Approximation*

Fig 4.13 *Influence of double-sided interchannel interference on Np and m for Pe=10^{-9} when calculated using the Chi-Square Approximation*

Fig 4.14 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on Np and m for Pe=10⁻⁶ when single-sided interchannel interference is considered*
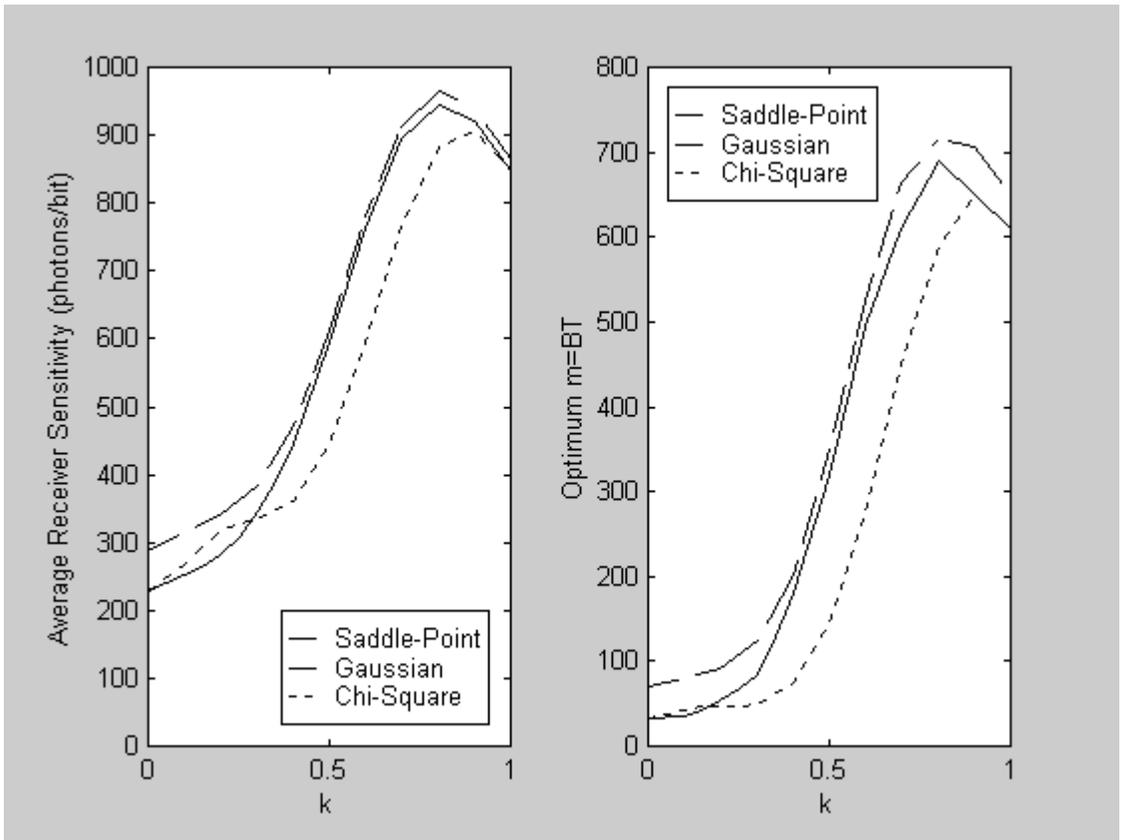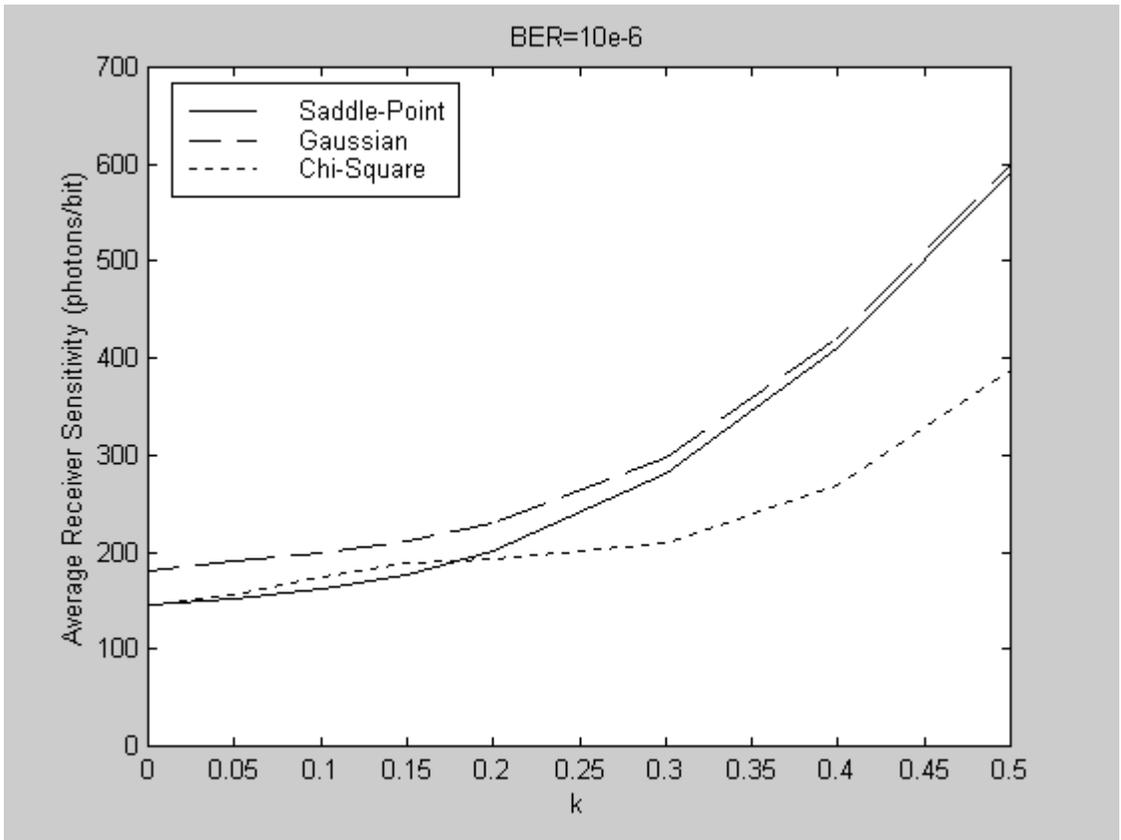
Fig 4.15 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on Np and m for Pe=10^{9} when single-sided interchannel interference is considered*

Fig 4.16 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on Average Receiver Sensitivity for $Pe=10^{-6}$ when double-sided interchannel interference is considered.*
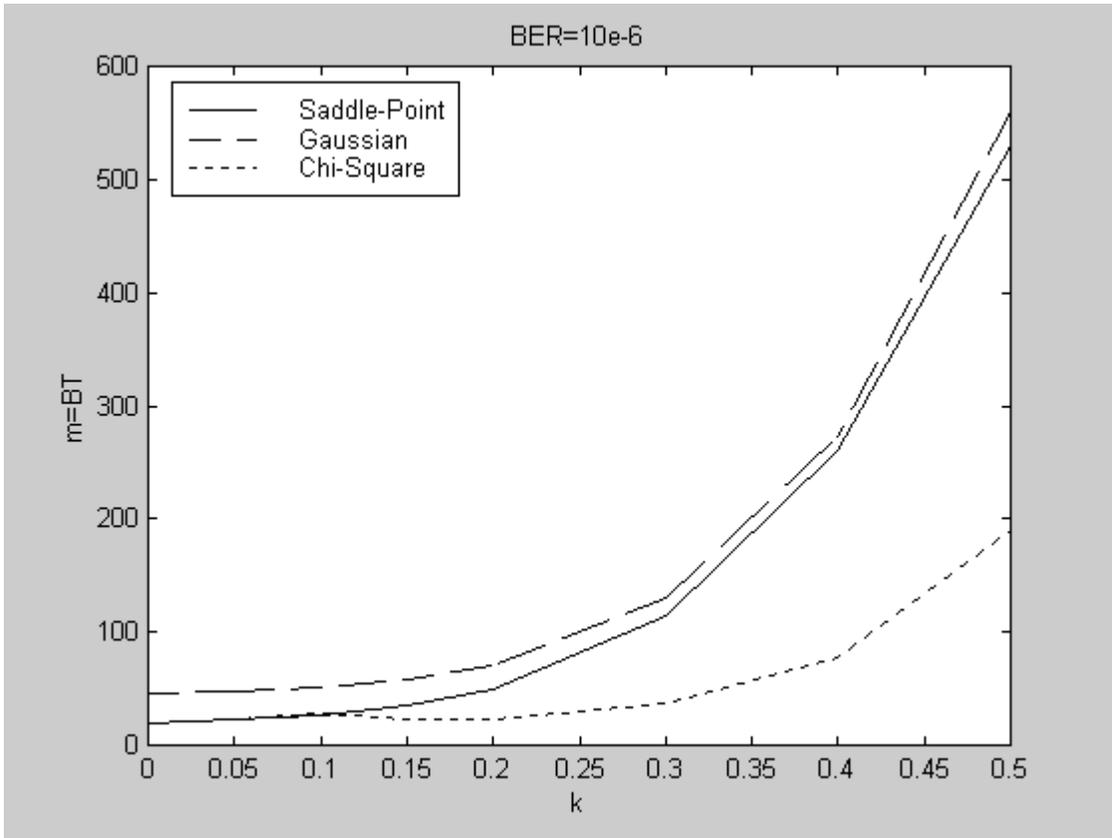
Fig 4.17 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on m=B_0T for Pe=10^{-6} when double-sided interchannel interference is considered.*
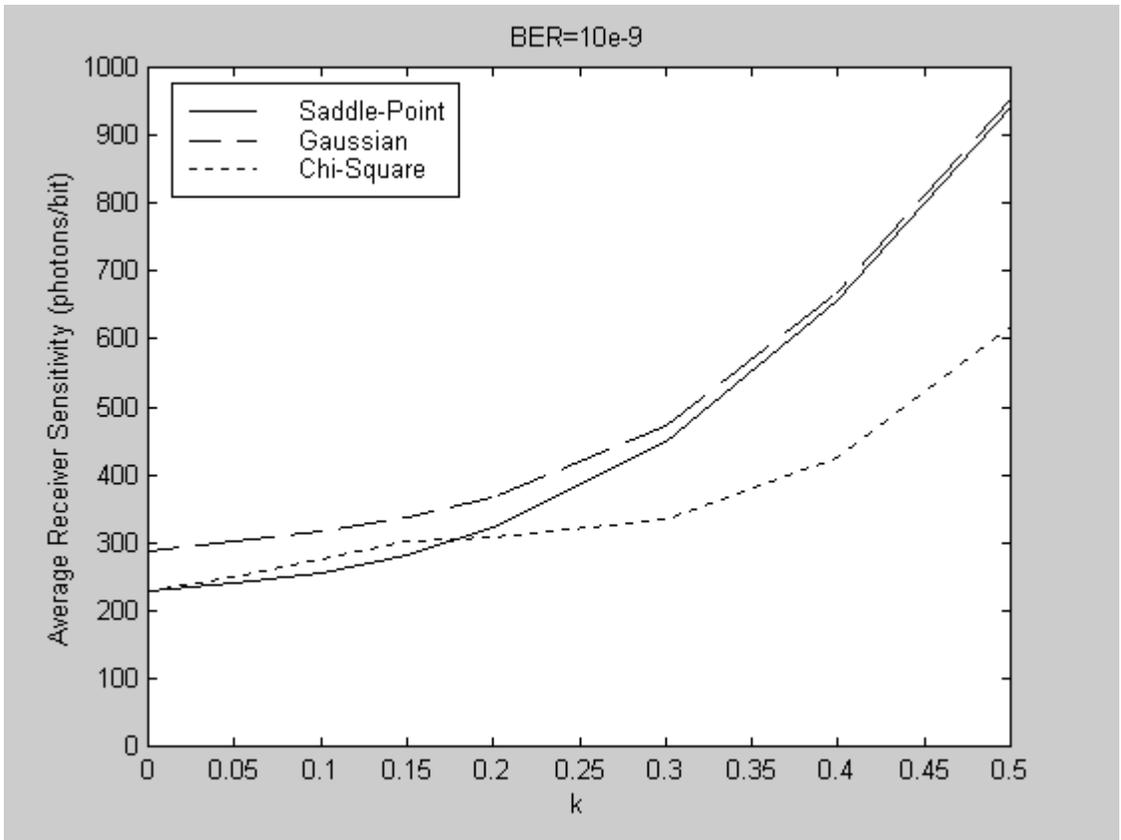
Fig 4.18 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on Average Receiver Sensitivity for Pe=10^{-9} when double-sided interchannel interference is considered.*
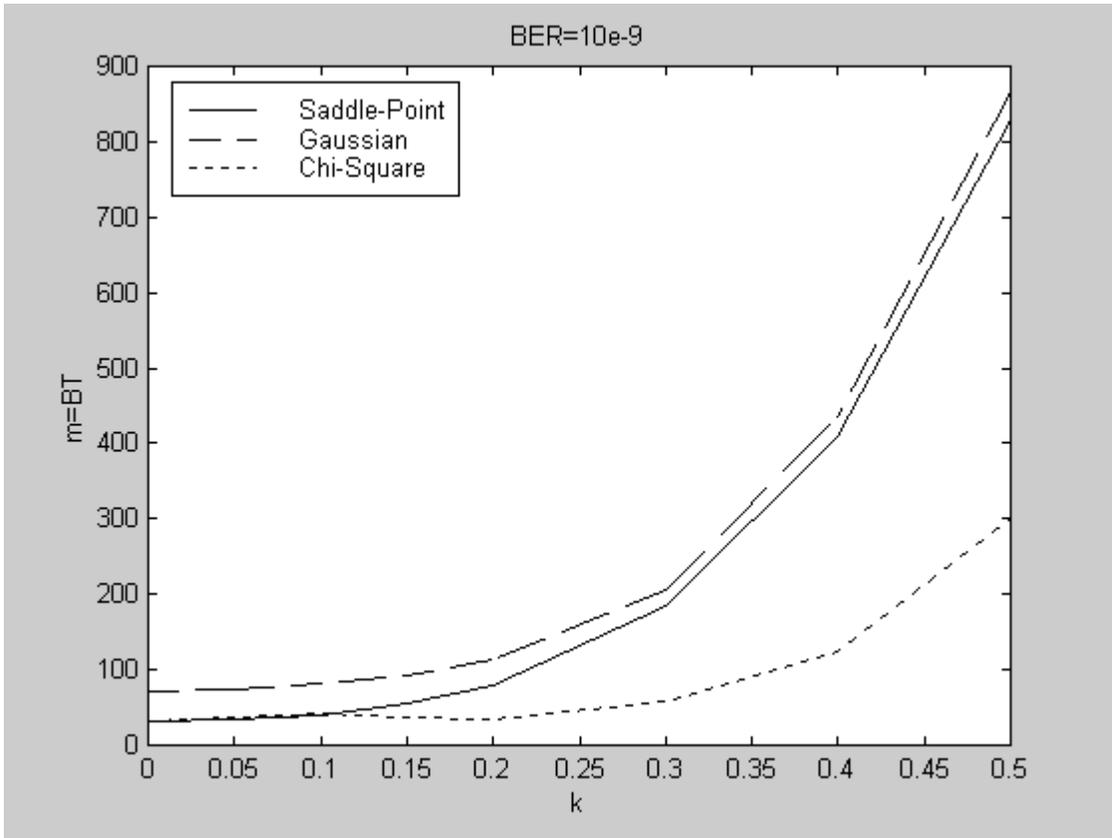
Fig 4.19 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on $m=B_0T$ for $Pe=10^{-9}$ when double-sided interchannel interference is considered.*
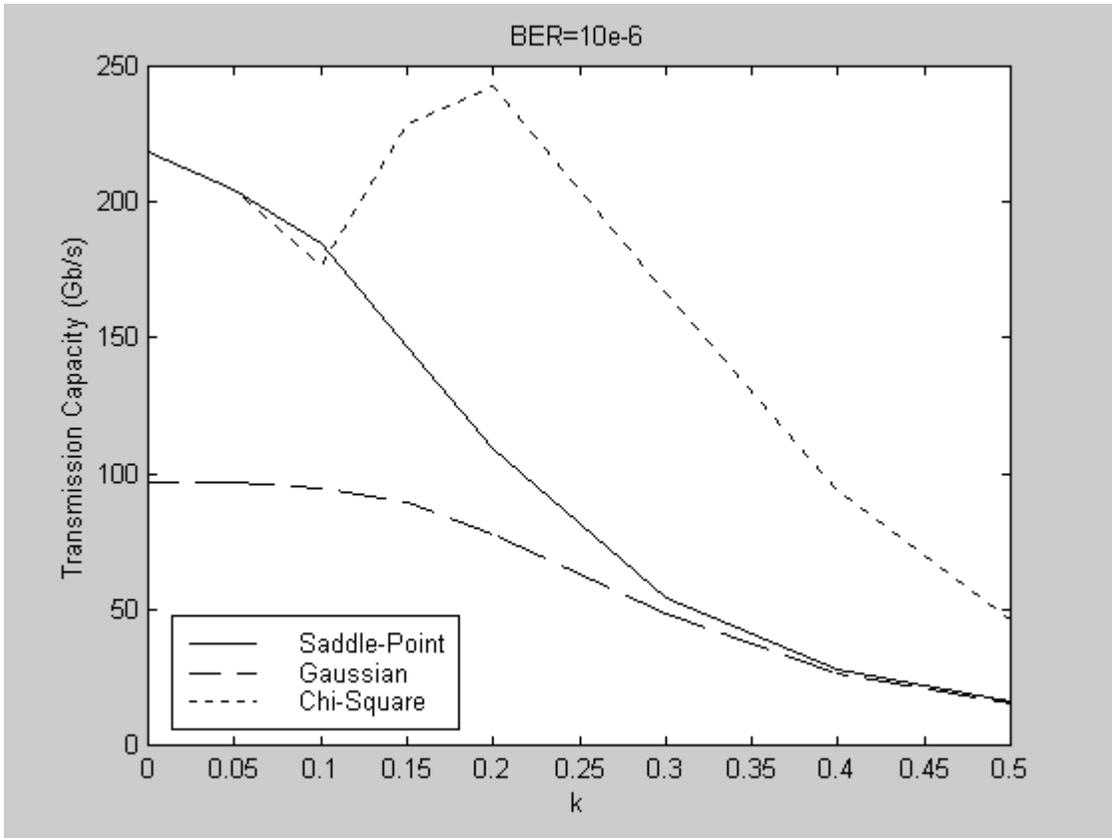
Fig 4.20 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on system throughput for Pe=10^{-6} when double-sided interchannel interference is considered.*
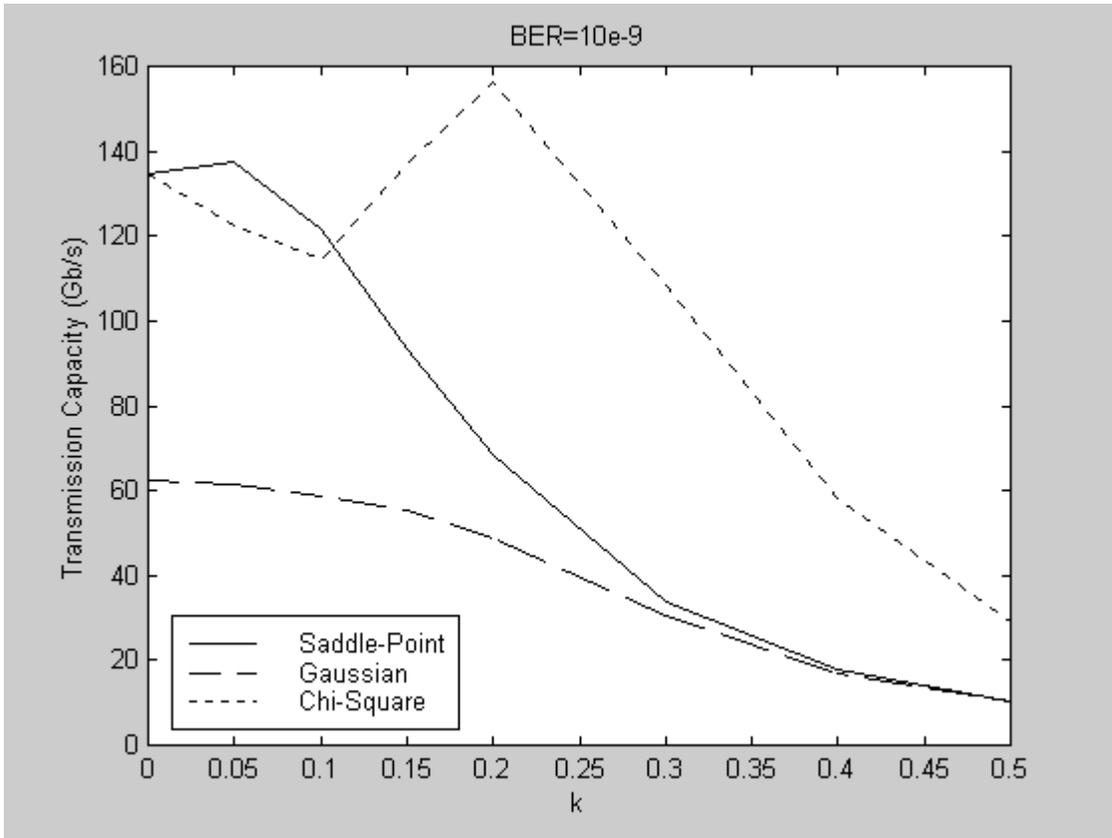
Fig 4.21 *Comparison between Saddlepoint, Gaussian, and Chi-Square Approximation regarding influence of channel overlap on system throughput for Pe=10^{9} when double-sided interchannel interference is considered.*