# The Effect of Bit Transmission Rate to the Receiver Sensitivity and BER Performance

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**Summary**
Thermal Noise is generated naturally by thermal agitation of electron in a conductor commonly found in opto-electronic device. In spite of the optical medium is totally immune to noises but it is not exception to occur in receiver parts. In communication, thermal noises have major influenced to the quality of receiver. It is directly proportional to the resistance and temperature. The lower the thermal noise the higher and expensive is this receiver sensitivity. This paper highlights the discussion of transmission rate that influence to BER performance improvement by increasing the receiver sensitivity. At same thermal noise value, decreasing the system transmission rate will increase the receiver sensitivity.

***Key words:***
*Transmission rate, receiver sensitivity, BER performance, Thermal noise.*

## 1. Introduction

Thermal noise is to be distinguished from shot noise, which consists of additional current fluctuations that occurs when a voltage is applied and a macroscopic current starts to flow. For the general case, the above definition applies to charge carriers in any type of conducting medium (e.g. ions in an electrolytes), not just resistors. It can be modeled by a voltage source representing the noise of the non-ideal resistor in series with an ideal noise free resistor [1].

The power spectral density, or voltage variance (mean square) per hertz of bandwidth, is given by [2,3]:

$$V^2_n = 4k_BTR \qquad (1)$$

where $k_B$ is Boltzmann's constant in joules per Kelvin, T is the resistor's absolute temperature in Kelvins, and R is the resistance in ohms.

The noise generated at the resistor can transfer to the remaining circuit; the maximum noise power transfer happens with impedance matching when the Thevenin equivalent resistance of the remaining circuit is equal to the noise generating resistance. In this case the noise power transfer to the circuit is given by [2,3]:

$$P = k_BT\Delta f \qquad (2)$$

where P is the thermal noise power in watts. Notice that this is independent to the noise generating resistance.

In communications, power is often measured in decibels relative to 1 milliwatt (dBm), assuming a 50 Ohm resistance. With these conventions, thermal noise at room temperature can be estimated as [2,3]:

$$P_{dBm} = -174 + 10\log(\Delta f) \qquad (3)$$

where P is measured in dBm.

## 2. Thermal noise vs Sensitivity

Thermal noise played an importantly role in order to determine the sensitivity for a photodetector. As the thermal noise become lower, the photodetector become more sensitive, however this value is depends to the data transmission rate [5,7]. For example, the sensitivity for a photodetector at -22 dBm for an optical network at the different data transmission rate is different. This value only depends to a parameter for photodetector, which is the thermal noise. Before conducting the simulation using the *Optisystem* software, the determination on the sensitivity value of the photodetector must be optimized [4]. This optimization process required a new extra circuit, which consists of several devices including variable attenuator, photodetectoro, BER analyzer, Bessel filter, optical power meter, and OSA.

The parameters that need to be optimized are the thermal noise and the maximum Q-factor. The network characterization process only can be proceeded after obtain the maximum noise value for the sensitivity of photodetector. Figure 1 and Figure 2 indicate the thermal noise and BER at sensitivity –22 dBm for different data transmission rate (OC-12 to OC-48). One of the operating wavelengths can be connected to the photo detection circuit through variable attenuator. The variable attenuator

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is used to set the magnitude of sensitivity, for example –22 dBm. This reading can be obtained through an optical meter that resumed to the variable attenuator. After carried out the optimization process, analyzing the BER may give the maximum Q-factor, while the photodetector giving the reading for maximum thermal noise. These thermal noise values are transferring into all photodetectors in the respective network for conducting the characterization process.

From the analysis of Figure 1, it has been clearly observed that the thermal noise is reduce almost double times by the raise of data transmission rate which also double times increased. Thus, it could be estimated that BER value has a closely relation with data transmission rate directly, with a factor approximately 0.5. The increase in data speed and it capacity need a powerful detection device that is has a low BER value. The existence of high BER value able to aggravated a data computation, which received in high speed and narrower bandwidth.

Figure 2 indicates BER right after optimization process for data transmission rate starting from OC-12 to OC-192 at sensitivity –22 dBm. The results verify that the sensitivity of photo receiver is inverse proportional to the value of thermal noise, in which the value is also difference and difference transmission rate at similar sensitivity value.

## 3. Bit Rate vs BER

This objective of simulation is to study the relationship between output power and operating distance at three different transmission rate which are OC-12, OC-24 and OC-48. Refer to Figure 3, we observed the profile of output power versus distance is similar to three different transmission rate. This indicates that the output is not effected by rate of data transmission. The study is carried out on ring optical network. The decrement of data transmission rate will increase the receiver sensitivity, thus the BER will also improved. This indicates in Figure 4. The decrement of transmission rate is similar to the increment of input injected power or regeneration via the amplifier gain. At OC-48, the maximum achievable distance is 350 km only but at OC-24, the distance is upgrade to more than 700 km using the same receiver. Furthermore, the BER performance is more excellence at OC-12 with the maximum distance is definitely farer as compare to the distance achieved at OC-24. This indicate that decrement of transmission rate increases the receiver sensitivity.

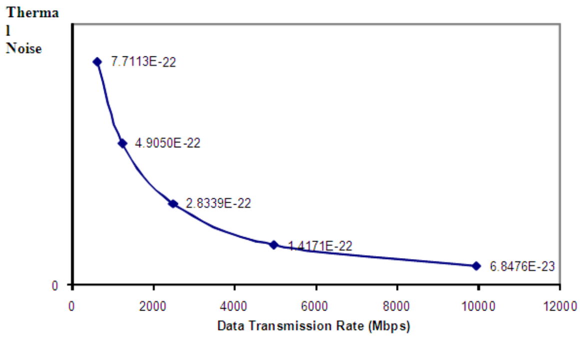


Fig. 1. Thermal noise values at different data transmission rate starting from OC-12 to OC-192 at sensitivity –22 dBm. The increment of speed and capacity of transmission data decrease the thermal noise exponentially.

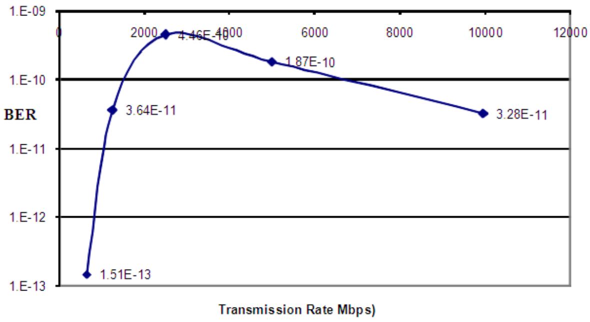


Fig. 2. Maximum BER at sensitivity –22 dBm for data transmission rate starting from OC-12 to OC-192.

## 4. Conclusion

This paper highlights the discussion on data transmission rate that influence the BER performance improvement by increasing the receiver sensitivity. At same thermal noise value, decreasing the system transmission rate will increase the receiver sensitivity, thus improve the BER performance. Our analysis shows the decrement of transmission rate is similar to the increase of input injected power or regeneration via the amplifier gain. At OC-48, the maximum achievable distance is 350 km but at OC-24, the distance is more than 700 km using the same receiver. As well as the BER performance is seem more excellence at OC-12 with the maximum distance is definitely farer than the distance can be achieved at OC-24. As conclusion, this indicates the decrement of data transmission rate increases the receiver sensitivity and without changing of receiver, the BER performance is improved when downgrading the system.

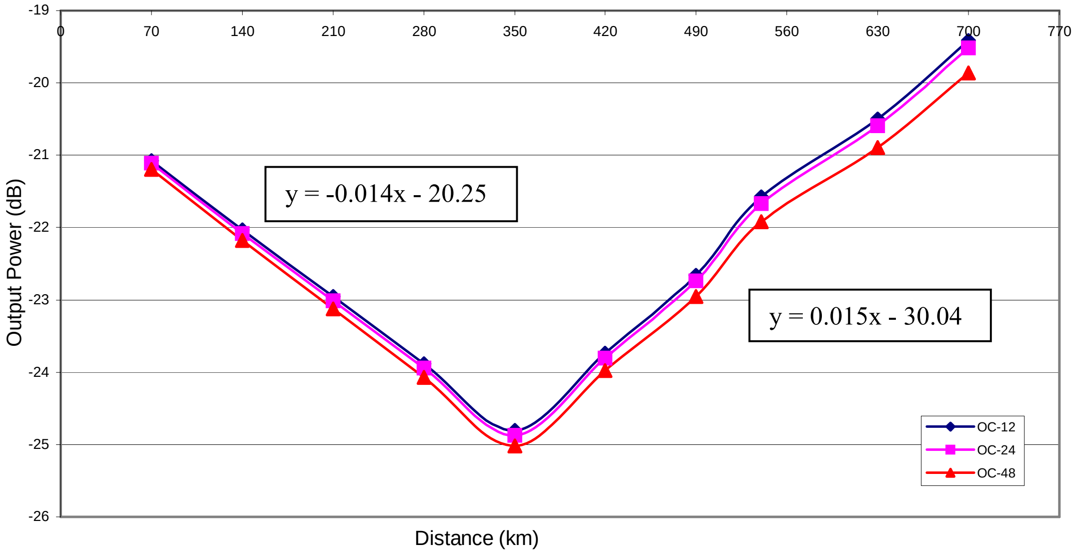


Fig. 3 The effect of transmission rate to the output power at wavelength 1530 nm measured at different distances up to 700 km.

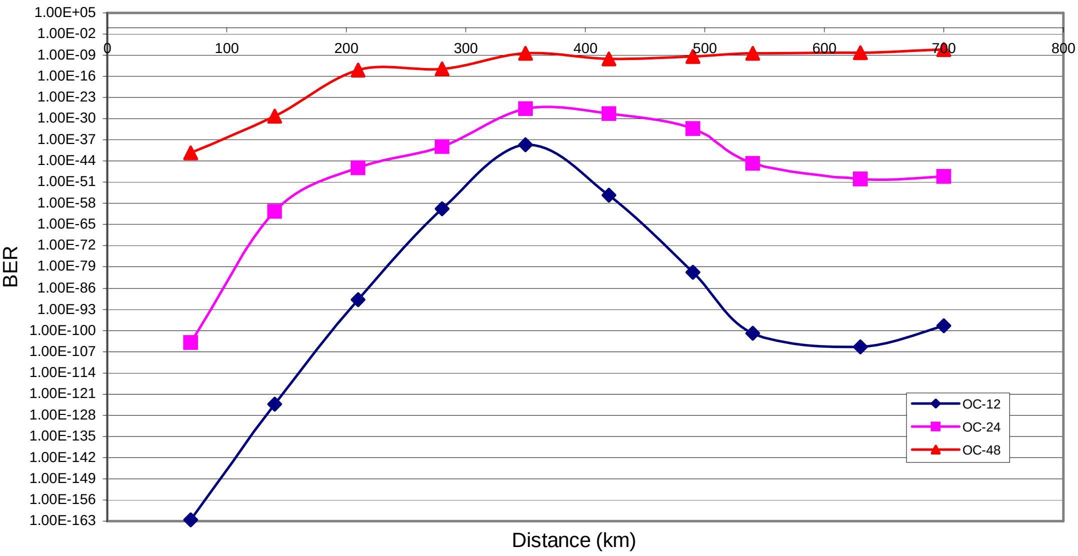


Fig. 4 The effect of transmission rate to BER performance at wavelength 1530 nm measured at different distances up to 700 km. The decrement of transmission rate increases the receiver sensitivity and BER is further improved from OC-48 to OC-12 using the same receiver.

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