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Analysis of Variation of BER with Input Power for Constant Bandwidth and Zero Crosstalk at Various Wake up Times

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Abstract - Huge energy resources (electricity) are consumed by the telecom-equipments in broadband enable access technologies. There is current need to minimize the energy consumption in access network technologies especially in passive optical network. This paper aims to analyse variation of BER with input power for constant bandwidth and zero crosstalk at various values of wake up time.

Keywords - Optical line terminal, Optical network unit, PON- Passive Optical Network, Downstream Traffic, Power Saving Method, TDM-PON, sleep mode and synchronization.

I. INTRODUCTION

It is estimated that 2-10% of the CO2 produced by human activity comes from Information and Communications Technologies (ICT) [3]. Such emissions are expected to rise steadily in the next years, due to the increase of users and increased utilization. Today most of access network segment is based on energy-demanding technologies and wireless access. However, even with the introduction of optical fibre in the access, the energy consumption is forecast to grow with the average access bit rate ssincrease [4]. Furthermore, the energy per bit requested by Optical Network Units (ONUs) of Passive Optical Networks (PONs) is at the top among the communications network devices.

II. PASSIVE OPTICAL NETWORKS

PON is a shared medium in which a fibre is passively split into many end user connections. The term passive refers only to the optical splitter, which work independently of external electrical power. Each end user has an ONU while the fibre terminates at a central office in an OLT (optical line terminal), which requires electrical power. Between the OLT and the ONU may be one or two stages of passive splitters which split the connection to multiple end points. The signal generated at core network need to be send towards requested ONU.

Power Saving Techniques

The common objective of all power saving techniques is to put ONU into lower power states. The power saving states into three categories: Power *shedding*, dozing, and sleeping. The approaches mainly differ in the behavior of the ONU transmitter and receiver. In general, the ONU transmitter is already burst-mode capable, i.e. it can turn on and off quickly during idle time slots to avoid adding noise contribution to the other ONU upstream data. On the other hand, turning ONU receiver on and off is far more challenging because the operation will require synchronization overhead to recover the clock from downstream data. During lower power states, the ONU also faces the choice to select what part of functions and services to turn off. In the power shedding mode, used when the ONU operates under battery power, the ONU powers off or reduces the power to non-essential part of functions and services only. In the dozing mode, the ONU keeps all the downstream functions operational but turns off the transmitter and ignores OLT bandwidth request when ONU does not have upstream traffic to send.

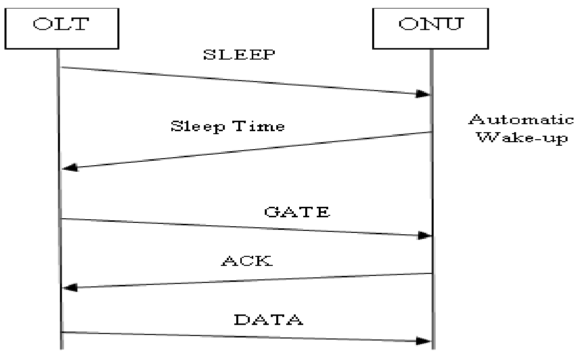

Fig. 1 Basic Concept of Power Saving Method.

In the sleeping mode, on the other hand, the ONU turns off virtually all the functions and services to gain the greatest power saving potentials. Sleeping mode into two sub-categories: *deep sleep* and *fast sleep*. In deep sleep mode, all ONU functions are turned off and any incoming downstream or upstream traffic is lost. In fast sleep mode the ONU maintains the timing (free-running and not synchronized to OLT) and traffic detection functions to maintain the ability to wake up from the sleep mode. Whenever new traffic arrives. During the transitional wake up time, the OLT would buffer the downstream traffic until ONU is fully awake. In the dynamic power save mode, the ONU shares similar transmitter and receiver behavior to the dozing mode but the operations of the ONU functions and services are more similar to the fast sleep mode.

When there is no data to be sent then OLT requests ONU to go to sleep mode by sending sleep message to ONU. The ONU puts itself to sleep mode and switches off. The user network interface goes to sleep mode as well. The user network interface is inactive in power ignoring scheme as well when network is idle. The sleep time for ONU is fixed at 2 msec. The ONU wakes up automatically after this sleep time. The OLT back end circuitry will continuously monitor for signal arrival. Between this duration, if signal arrives, the OLT signals ONU to wake up by sending GATE message. The ONU will acknowledge this message by sending ACK signal and ONU become active and start receiving data from OLT. During this transition process, from sleep to active or active to sleep some power is consumed as well but still less then power wastage during idle mode.

Sleep Mode Scheduling Energy Saving Technique in TDM-PON

In a TDM-PON (time division multiplexing PON) network the length of inactivity periods strongly depends on the particular applications that the customer is using and on the traffic load conditions throughout the whole network. Despite these factors, still it is possible to obtain an estimation of the idle period. This can be achieved by exploiting the statistical properties of the traffic, but some error must be tolerated. The tolerance level mainly depends on the service-specific requirements because different service types usually require different frame rates and show different sensitivities to traffic delay. This thesis investigates and proposes a *sleep mode* technique where the length of the sleep periods for each ONU is computed with a statistical method by monitoring the inter-arrival times between downstream frames. The scheduling mechanism is then divided into two different methods in order to preserve quality of service when delay-sensitive services are active but save more energy when the traffic is not so critical in terms of latency.

III. BIT ERROR RATE CALCULATIONS

Bit Error Rate can be calculated with and without Crosstalk using some equations.

Bit Error Rate: The number of bit errors that occur within the space of one second. This measurement is one of the prime considerations in determining signal quality. The higher the data transmission rate the greater the standard. The BER is an indication of how often data has to be retransmitted because of an error. Too high a BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data since the BER might be reduced, lowering the number of packets that had to be resent. For most practical networks, this requirement of BER is 10^{-12} (~ 10^{-9} to 10^{-12}), which means that a maximum one out of every 10^{12} bits can be corrupted during transmission. Therefore, BER is considered an important figure of merit for WDM networks; all designs are based to adhere to that quality. BER in system is calculated by the equation:

$$BER = \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right) \approx \frac{\exp\left(\frac{-Q^2}{2}\right)}{Q\sqrt{2\pi}} \qquad \text{(eq. 1)}$$

Here Q is a function proportional to the receiver signal-to-noise ratio (SNR). It is expressed as:

$$Q = (R_b * P_s) \wedge 2 / \sqrt{(\sigma_{ase} \wedge 2 + \sigma_c \wedge 2)} \qquad \text{(eq. 2)}$$

Here

Rb = Bit Rate; in telecommunications and computing, bitrate (sometimes written bit rate, data rate or as a variable *R* or f_b) is the number of bits that are conveyed or processed per unit of time. The bit rate is quantified using the bits per second (bit/s or bps) unit.

Ps = signal power

σc = Crosstalk.

σase = ASE (amplified spontaneous emission) noise induced by parametric gain and spontaneous Raman scattering in optical fiber Ramen amplifier.

It is an unwanted noise.

$$\sigma_{ase} = \sqrt{((G-1) * n_{sp} * h * \nu * \beta_0) z} \qquad \text{(eq. 3)}$$

Here

G = Gain

*n*sp = Spontaneous Emission Factor or Population-Inversion Factor

h = Planck's constant = 6.634*10^-34

ν = Frequency of the signal = c/L

c = speed of light = 3*10^8

L= wavelength

βo = Band Width a measure of the width of a range of frequencies, measured in hertz.

In ideal case, σc = 0; which is with no cross talk, equation 2 becomes:

$$Q = (R_d * P_s) \wedge 2 / \sigma_{ase} \quad [\sigma c = 0 \text{ for ideal case}]$$

For different values of bandwidth, BER without crosstalk can be calculated using Eq. 1 for the above equation of Q. Bandwidth can be 2* Rb, 4* Rb, 6* Rb etc. Putting in the values in equation 2, we can find the value of Q and putting this value in equation 1 we can calculate the value of BER for the system. In order to calculate Power Penalty from in-band Crosstalk, we first calculate the power for without crosstalk then for with crosstalk. The difference between the two gives the Power Penalty.

IV. RESULTS AND ANALYSIS

Analysis of Bit Error Rate with Input Power for Constant Bandwidth (2*R_b) and Zero Crosstalk (Ideal Condition) at various Wake Up times.

Variation of BER with input power for constant bandwidth (2*R_b) without considering crosstalk effect (zero crosstalk) at various wake up times have been analyzed in the following cases.

Case 1 When Bandwidth is 2*R_b , Zero Crosstalk and Wake Up time is 1 ms.

The effect on BER when bandwidth is constant i.e. 2*Rb , crosstalk is zero and wake up time is 1 ms is shown in Fig. 5.5.3 (a). It can be seen from figure that BER remained constant at 10^{-49} for various values of input power. It can be concluded that there is no effect of wake up time on BER. The mean and standard deviation value of BER is 5.713e-050 and 4.336e-050 respectively.

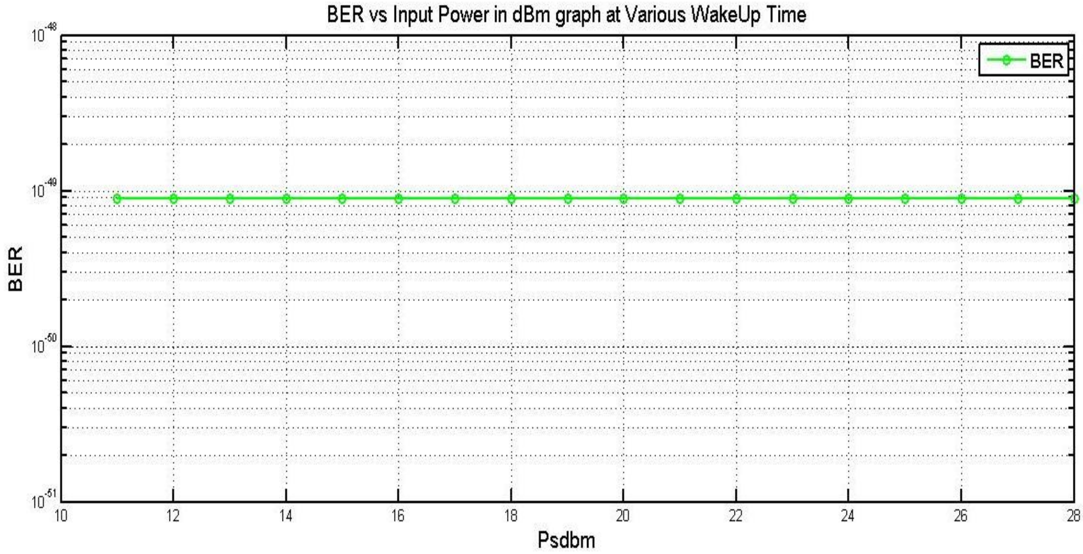

Fig. 5.5.3 (a) BER vs Input Power when Wake Up time is 1 ms.

Case 2 When Bandwidth is 2*R_b , Zero Crosstalk and Wake Up time is 2 ms.

When wake up time is 2 ms (bandwidth and crosstalk remained same), the plot of BER with input power is shown in Fig. 5.5.3 (b).

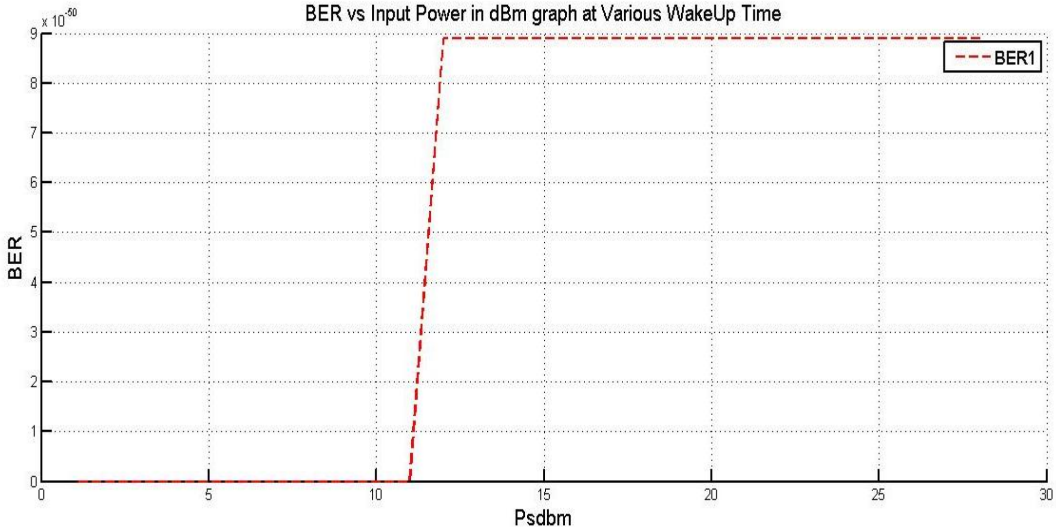

Fig. 5.5.3 (b) BER vs Input Power when Wake Up time is 2 ms.

It can be seen from figure that BER remained 0 till 11Psdbm then increased to $9*10^{-50}$ at 11 Psdbm and remained constant afterwards. Mean and standard deviation value of BER is 5.396e-050 and 4.42e-050 respectively.

Case 3 When Bandwidth is 2*R_b , Zero Crosstalk and Wake Up time is 4 ms.

When wake up time is 4 ms, the plot of BER versus input power is shown in Fig. 5.5.3 (c).

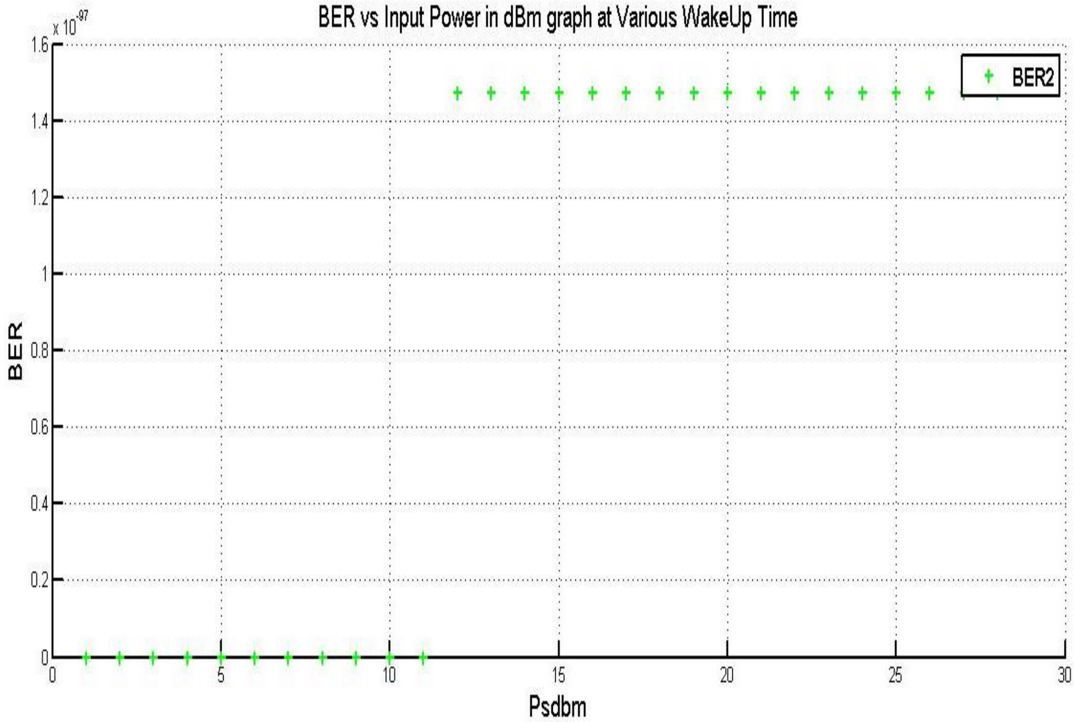

Fig. 5.5.3 (c) BER vs Input Power when Wake Up time is 4 ms.

It can be seen from figure, BER remaine 0 till 11 Psdbm then increased to $1.5*10^{-97}$ at 12 Psdbm input power. Mean and standard deviation value of BER is 8.947e-098 and 7.329e-098 respectively.

Case 4 When Bandwidth is $2*R_b$, Zero Crosstalk and Wake Up time is 8 ms.

The plot of BER versus input power when wake up time is 8 ms is shown in Fig. 5.5.3 (d). It can be seen from figure, BER remained 0 till 10 Psdbm then increased to $1.5*10^{-97}$ at 11 Psdbm input power. The mean and standard deviation value of BER is 9.743e-098 and 7.191e-098 respectively.

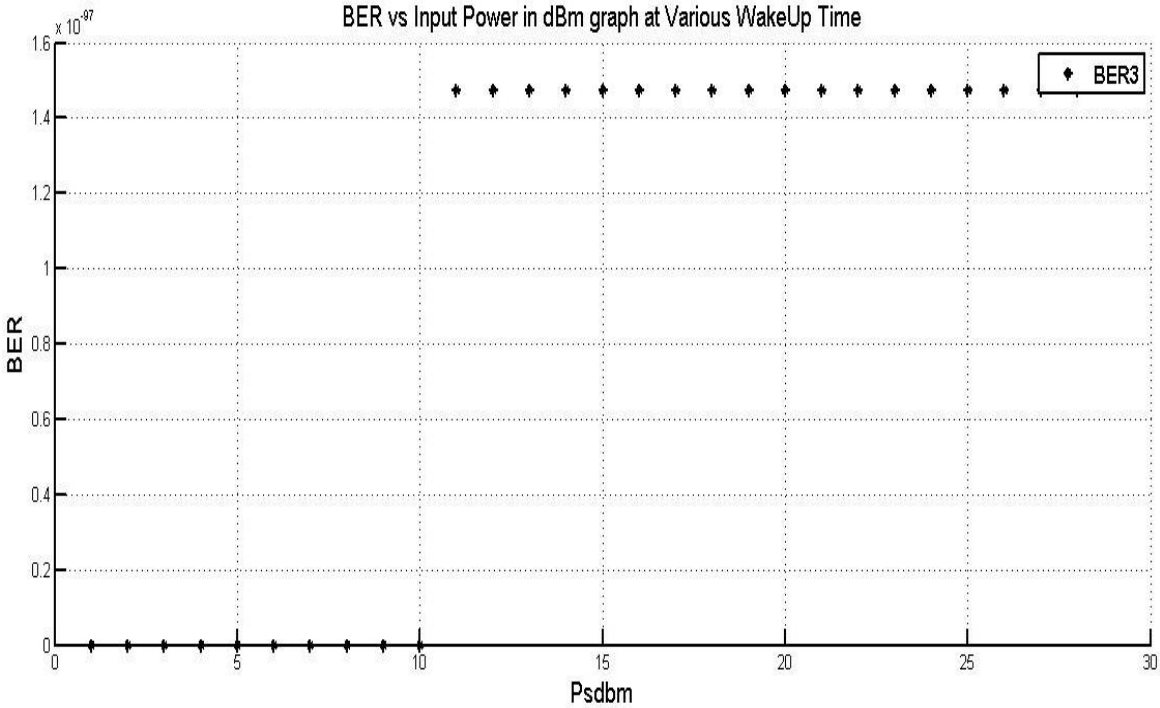

Fig. 5.5.3 (d) BER vs Input Power when Wake Up time is 8 ms.

Case 5 When Bandwidth is $2*R_b$, Zero Crosstalk and Wake Up time is 16 ms.

When wake up time is 16 ms, the plot of BER with input power is shown in Fig. 5.5.3 (e).

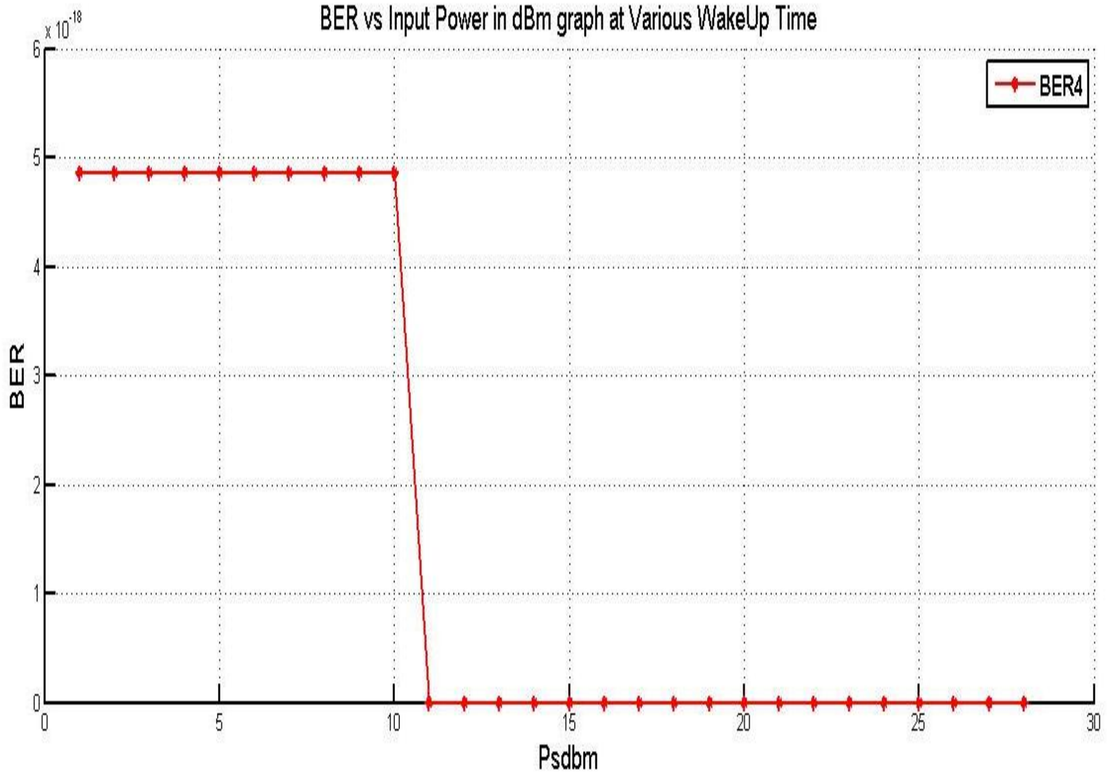

Fig. 5.5.3 (e) BER vs Input Power when Wake Up time is 16 ms.

It can be seen from figure that initially BER remained constant at $4.9*10^{-18}$ till 10 Psdbm then decreased to 0 at 11 Psdbm and remained at 0 value thereafter. The mean and standard deviation value of BER is 1.735e-018 and 2.371e-018 respectively.

Case 6 When Bandwidth is $2*R_b$, Zero Crosstalk and Wake Up time is 32 ms.

When wake up time is 32 ms, the plot of BER with input power is shown in Fig. 5.5.3 (f).

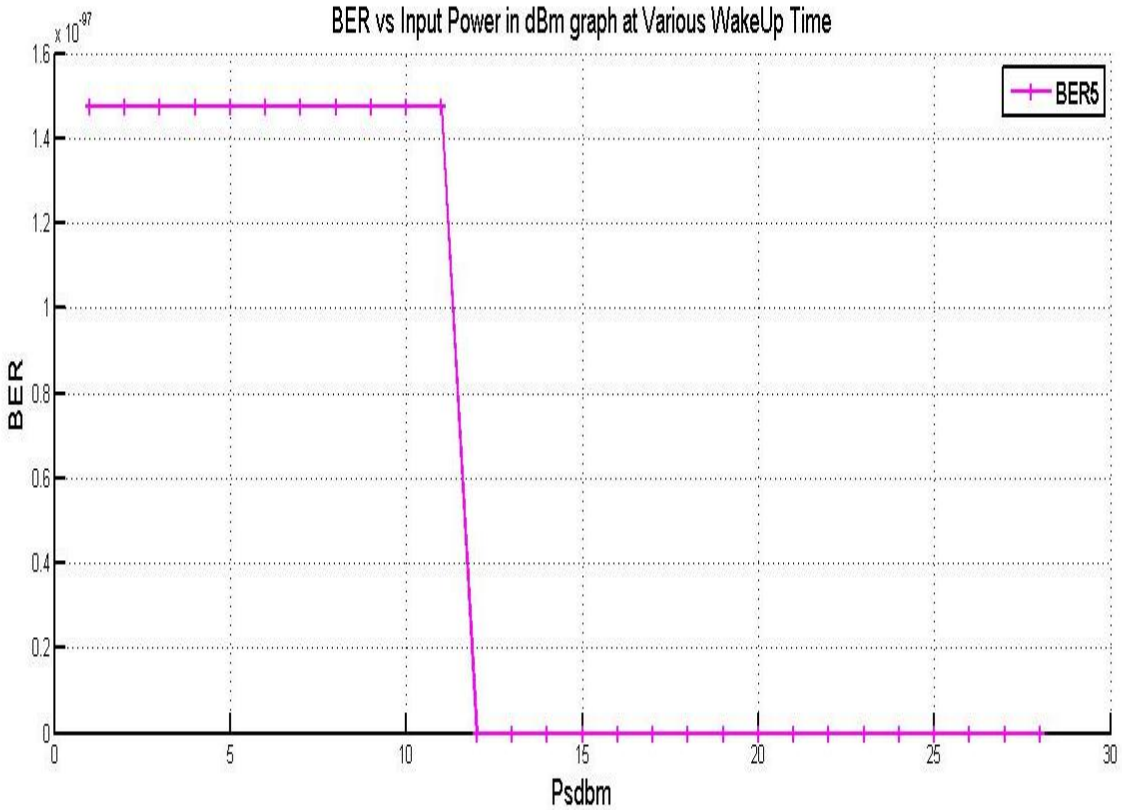

Fig. 5.5.3 (f) BER vs Input Power when Wake Up time is 32 ms.

It can be seen from figure that BER decreased from $1.5*10^{-97}$ at 11 Psdbm to 0 at 12 Psdbm input power. The pattern of this graph and above graph is different from the other graphs where the BER was increasing with input power.

Case 7 When All Graphs were superimposed

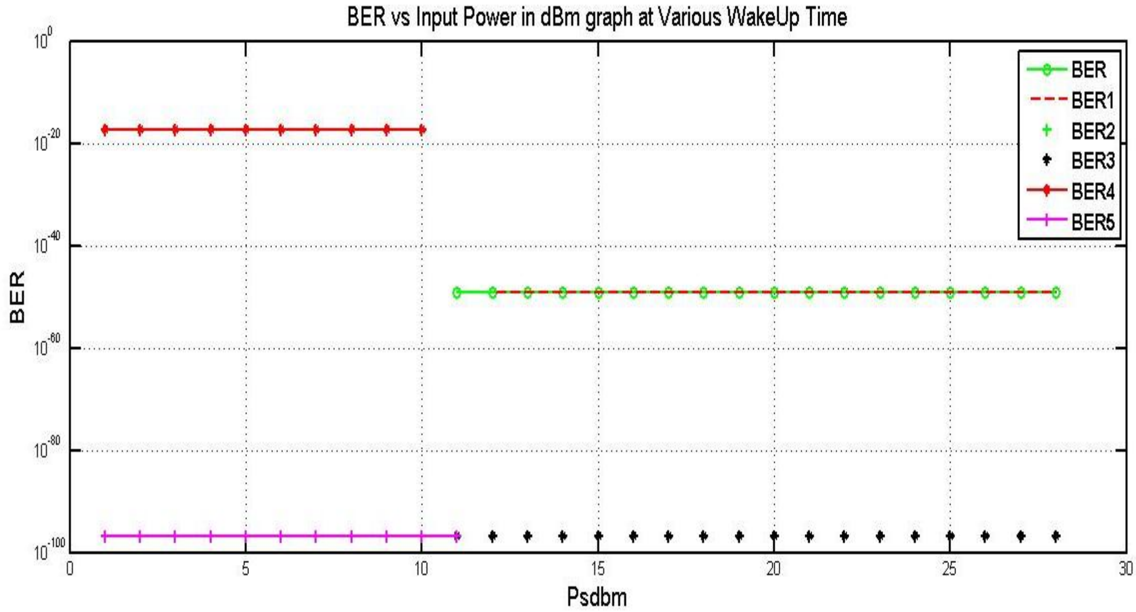

Fig. 5.5.3 (g) BER vs Input Power when all Graphs were superimposed

V. Conclusion

By clearly observing the graphs of BER with input power for constant bandwidth and zero crosstalk at various wake up times, it has been investigated that BER was constant when wake up time was 1 ms. BER increased with input power for wake up time 2,4 and 8 ms and BER decreased with input power for wake up time 16 and 32 ms.

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