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Improvement of the Performance of OCDMA By Using Error Correction Code

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Abstract

In this paper a new approach is proposed for enhancement of the data transmission optical communication systems by applying CDMA technique based error detection and correction code. This paper includes the study and analysis of the different important variables for optical CDMA system, and focuses on increasing the system performance by selecting the optimum values for different variables to reduce the multiple access interference problems and also by applying error detection and correction code with selecting of the best polynomial. The detected and corrected code technique is more active because the selection of the optimum values from the variables network helps to decrease the interference sources and noise to lower value. The selection of optimum values helps in reducing the number of the added correct bits in the transmit code word consequence enhancement of the system performance because the channel is exploited to transmit the information. The results show enhancement in system performance when selecting optimum value of received power (2µ Watt), where the enhancement ratio is equal to (23%). Also this paper proves the use of error correction technique became very active with the optimum values of received power (2 µWatt), so the improvement ratio with applying ECC is equal to (22%).

Keywords: OCDMA, optical communication systems, forward error correction code

تحسين أداء منظومة الاتصال البصري المتعدد بالتقسيم ألتشفيري باستخدام تقنية تصحيح الخطأ المشفر

الخلاصة

اقترح البحث الحالي طريقة لتحسين نقل البيانات في أنظمة الاتصال الضوئية باستخدام تقنية الاتصال المتعدد بالتقسيم ألتشفيري بواسطة كشف وتصحيح الأخطاء. يتضمن البحث الحالي دراسة وتحليل مختلف المتغيرات المهمة لنظام الاتصال المتعدد بالتقسيم ألتشفيري بهدف تقليل مشكلة التداخل التي تحصل بسبب تعدد المستخدمين, كذلك بتطبيق عملية كشف وتصحيح الأخطاء واختيار أفضل شفرة (متعددة الحدود). إن تقنية كشف وتصحيح ألأخطاء أصبحت أكثر فاعلية بسبب الاختيار الأمثل لقيم المتغيرات للنظام والتي ساعدت على تقليل مشكلة التداخل والضوضاء إلى اقل قيمة.وكذلك إن اختيار القيم المثلى ساعد في تقليل عدد رموز التصحيح (bits) المرسلة مع ألكلمة المشفرة(codeword) وبالتالي تحسين أداء النظام بسبب ألاستغلال ألأمثل للقناة لنقل المعلومات. أظهرت النتائج تحسن واضح عند اختيار القيم المثلى, حيث كانت نسبة التحسن مساوية إلى (23%). أيضا أثبت البحث الحالي أن استخدام تقنية تصحيح الخطأ أصبح أكثر فعالية إذا اعتمدت القيم التصميمية للنظام بالشكل الذي يؤدي إلى أن تعمل المنظومة بأفضل حال ولهذا كانت نسب التحسين عند تطبيق تقنية تصحيح الخطأ

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1.Introduction

Optical signal processing would be advantageous since it can potentially be much faster than electrical signal processing and the need for photoelectron-photon conversion would be obviated. Code division multiple access (CDMA) is a multiple access protocol which is efficient with low traffic and has zero access delay [1]. OCDMA offers an interesting alternative for LANs because neither time management nor frequency management of all nodes is necessary [2]. OCDMA can operate asynchronously, without centralized control, and does not suffer from packet Collisions (in case of well designed codes with reduced multi-user interference); therefore, very low latencies can be achieved. Dedicated time or wavelength slots do not have to be allocated, so statistical multiplexing gains can be high [3]. Also Optical Code Division Multiple-Access: Enabling Future LANs is an excellent candidate for future LANs. It may provide concurrent access by a large number of users without access delay [4].

There are three important objectives in this paper, the first objective is design and implementation of the simulation realistic model for optical code division multiple access in local area network. The second objective is study and analysis of the system behavior with different variables such as codeword weight, codeword length, threshold of detector, and transmitted power. Also this research studies the effect of multiple access interference problems (MAI) with different numbers of supported users (N) based on two cases of code word weight (w).

Thirdly, error correction code technique is applied to three types of polynomial in forward error correction technique.

2. System Model

To realize the aims of this paper in clear and organized form there must be description of all variables and data and what follows from processing and outcome within system Figure (1) having alternate relationship between elements. The following step illustrates these procedures which contain:

1-Summation and analysis of information.

2-Presentation of the outcome of the system.

3-Applying error detection and correction code.

4-Evaluation of outcome and limiting available modifications.

2.1 Simulation Of Convolution Optical CDMA LAN System

Depending on procedures of this work, the optimum values of the system can be calculated according to following:

2.1.1 System Input

Choose the receiver type of detector which is limited by the following equation [9]: .

$$l_{so} = \frac{qh}{hf} P_{res} = R_d P_{rec} \; (Amper \;) \;..(1)$$

$$R_d = \frac{qh}{h.f} Amper / watt ....(2)$$

Where

a l_s: Arrival rate of incident photon due to chip (1) transmission in the signature sequence.

h : the PIN quantum efficiency of the photo detector.

P_{rec}: received power at optical correlate.

h : the Plank 's constant .

f : the optical carrier frequency.

q : magnitude of electron charge .

R_d : Responsively of photo detector

$h.f$: the photon energy.

down link wave length=1.55µm.
up link wave length= 1.3µm.

2.1.2 Choose the Type of Desirable Design Area

-LAN has a transmission distance relatively short (≤ 10 Km) [10].

-Fiber losses as well as the dispersive and non linear effects occurring inside fiber are not of much concern for LANs.

2.1.3 Optical Power Budget or Loss Budget

If the signal is too weak when it reaches the far end of the system the data will be difficult to separate from the background noise [10].

2.1.4 Limitation on the Received Power

The receiver power must be high enough to keep the BER to a low value, and the received power must be low enough to avoid damage to the receiver [10].

2.1.5 Limitation On The Transmitted Power

On cost and safety it is good to keep the transmitter power to the minimum acceptable value [10].

2.1.6 Calculation Of The Transmitter Power

The following steps show the calculation at the transmitter power[10]:

To find the minimum power losses for the system which is due to the:

1-Fiber
2-connector
3-Splices.
4-Aging losses.
5-Repairs.
6-Spare.

The values of these items are obtained from the manufacturer catalog [7].

-The attenuation of the fiber will contribute approximately 0.5 dB over 1Km or 5dB over 10Km. Other losses in connector and optical filtering are assumed to be 5 dB.

-For a system with 32 users the losses in the optical splitter will be at least 15 dB. To make up for the losses on optical amplifier can be added after the spreading at the sender.

-The summation of all power losses is equal to (25) dB.

Figure (3) illustrates the block diagram of losses in optical CDMA LAN system for star topology.

2.1.7 Calculation of the Minimum Received Power

The transmitter must supply enough power to overcome the worst case losses and still meet minimum power level requirement of the receiver, the receiver minimum power level is a large negative number decibels. This means that the power level is very small. The transmitter output must be greater than this level and therefore the numerical value of decibels must be less negative [10].The minimum received power can be determined where receiver need it to operate reliably with BER below a specified value or (10^{-9}), which is equal (1.61 micro watt) or (-57.13) dB depending on equation (1).

2.1.8 Calculation Of The Minimum Transmitter Power

The minimum transmitter power = minimum receiver power + losses ….. (3)

which is equal to (460.25) µ watt or (-33.37) dB. The light source with the nearest value of output power available is 500 µ watt or (-33 dB).

2.1.9 Calculation Of The Maximum Receiver Power

To calculate the maximum receiver power the following equation is used [10]:
(Transmitter power – minimum losses) or (5.88 micro watt)

$$= -52.3dB \qquad \ldots\ldots (4)$$

The benefit of this value is to know how much power would be received without damaging the receiver. The values of multiple access interference is calculated with the different values of number simultaneous users for two cases of code word weight i.e (w=5 ,w=7) with four values of threshold (16, 17, 18, 22) and fixed value of code word length (L=255) By using the equation (5)[8],

$$I_{in} = \sum_{i=0}^{N-1} \binom{N-1}{i} \left(1 - \frac{w^2}{2L}\right)^{N-1-i} \left(\frac{w^2}{2L}\right)^{i} \quad \ldots \ldots(5)$$

where:
N: number of simultaneous user.
i: threshold of detector.
w: codeword weight.
L: codeword length.

Depending on the equation (1) it is possible to generate the information matrix with dimension of (255,247). The values of multiple access interference are added to each chip with the effect that the thermal noise and shot noise is obtained by using equation (6), (7) respectively[9].

$$s_T^{\,2} = \frac{4k_B T}{R_L} Fn\Delta f \quad \ldots\ldots (6)$$

$$s_{sh}^{\,2} = 2qIB_e \quad \ldots..(7)$$

where:
K_B: Boltzmann's constant.
T: absolute temperature.
Fn: noise figure.
Δ_f: the electrical bandwidth.
R_L: receiver resistance.
Q: electron charge.
I: light intensity.

The new form of equation (1) will be

$$l_s = l_{so} + \left(I + \sqrt{s^2_{th} + s^2_{sh} + s_I^{\,2}} \right) ..(8)$$

where:
l_{so}: the chip transmitter.
I: is the multiple access interference.
s^2_{th}, s^2_{sh}, s^2_I the thermal, shot noise and interference in form of additive white Gaussian noise.

In each case the received power (P_{rec}) varies in three cases i.e. (2, 3, 5) μwatt and is calculated the following:

1. **Calculating the Signal to Noise Ratio (SNR)**

In this section, the signal to noise ratio is calculated and the effects of increasing power transmit on the system performance can be seen, and to determine the optimum power which operates the suggested system with the best case, depends on the following equation [9]:

$$SNR = 4Q^2 \quad \ldots.. (9)$$

where Q: factor which equals

$$Q = \frac{I_1 - I_0}{\sigma_1 + \sigma_0} \quad \ldots.(10)$$

When logic zero is received, no MAI appears i.e $s_o = 0$, and when logic one is received the MAI appears, and the dignity of equation (10) will be $(s_1 + s_o + s_I)$, then the Q factor can be calculated by the <u>*new propose form of equation (11):*</u>

$$Q = \frac{I_1 + I_o}{s_1 + s_o + s_I} \quad \ldots\ldots (11)$$

Recompense to the equation (9) yields

$$SNR = 4.\left(\frac{I_1 + I_o}{s_1 + s_o + s_I}\right)^2 \;\text{..... (12)}$$

where $I_1 = 2R_d\, P_{rec}$ ..... (12-1)
$\sigma_1 = (\sigma^2_s + \sigma^2_T)^{1/2}$ .. (12-2)
$I_0 = 0$ ..... (12-3)
$\sigma_0 = \sigma$ ...... (12-4)

2. Calculating the Bit Error Rate (BER)

In this section, the bit error rate is calculated, to show how the performance of optical CDMA networks is enhanced by applying the all different states. The value of BER can be calculated depending on equation (13) as follows [9]:

$$BER = \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right) \approx \frac{\exp\left(-Q^2/2\right)}{Q\sqrt{2p}} \;.(13)$$

The procedures of all steps of present work are shown in block diagram, Figures (4) and (5).

2.2 Applying the Error Correction Code

In this section, forward error correction code technique is applied to see the important error correction code in optical CDMA system.

2.2.1 Encoding

Applying of forward error correction code technique is accomplished corresponding to three types of polynomials which are a (255,247), a (255,239), and a (255,223)[10][11].By these polynomials the correct bits are generated and added to the message bits as follows:

The first polynomial (255,247) can generate the code from, The polynomial generates correct bits equal to (8), where this polynomial is not loaded on the channel, this means ability to exploit the channel to transmit high data rate. The principle of choosing this polynomial is supported at the first system analysis when we choose the optimum power (2μWatt), in addition to the other variables which yield low interference value. Also the system has high data rate which means that the received data must be received with low error and ability to apply error detection and correction technique.

The technique which is applied in this work is known as forward error correction (FEC) Figure (2) [10, 11]. The codes are generated by program and added to the message to form codeword that is provided to transmit. Same steps are conducted with the second and third polynomials (255,239), (255,223) but with correct bits equal to (16) and (32) respectively.

2.2.2 Channel Transmitter

After generating code by program and adding the message to it, the channel transmit is also generated by program.

The noise and the source of interference are added to the code transmit in addition to adding the attenuation values which result in all parts of the system. All noise source and interference that happen during transmitter and the attenuation are shown in detail in section (2.1.6).

2.2.3 Receiver

After the code word is received from the transmit channel, the data is sent to the detection system.

In this section the error is caused by the noise and interference which leads to change the information detected and corrected.

The following steps show the procedure of detecting and correcting code [11]:

1-Compute the syndrome of **r**, $\mathbf{r}.\mathbf{H}^T$

2-Locate the coset leader $\mathbf{e}_l$ whose syndrome is equal to $\mathbf{r}.\mathbf{H}^T$ .then $\mathbf{e}_l$.

is assumed to be the error pattern caused by the channel.

3-decode the received vector **r** into the codeword **v*= r+e$_l$**

Appendix (A) shows the flowchart for all cases covered in the presented work.

3. Simulation Results

The simulation results for the suggested system are divided into two main parts, the first part demonstrates enhancement of the performance of the optical CDMA system by selection of the optimum values of variables such as transmitted power, code word weight, code word length, and threshold value of detector. The second part focuses on the results of the optical CDMA with error detection and correction code using three types of polynomials with the measured Bit Error Rate depending also on investigating the following point: code word weight, received power, and four values of threshold detector. First, the results show the effect of the relationship between numbers of users versus BER on the behavior of OCDMA system for three values of code word weight, and show the effect of code word length with three values of code word length. Second, they show the effect of relationship between the number of users versus SNR (dB) for two cases of code word weight and for four values of detector threshold with varying the received power. Thirdly, they show the relationship between the number of users versus BER with two values of weight (w=5 ,w=7), fourthly, error detection and correction code technique are applied to three types of polynomials at optimum received power (2µwatt).The results in Figure (6) show that the code word weight has a great effect on the system performance, where the error ratio is equal to (10^{-3}) when varying the word weight from (9) to (5) for the same number of users.

Figure (7) shows the optimum selection of code word length has given the best improvement of the system performance, where it can be noticed that the ratio of improvement when the length is changed from (500) to (1500) is equal to (13%) for the same number of users.It is necessary to take into account the quality of optical detector, Figure (8) and Figure (9) show the improvement in performance. Also it can be noticed that the ratio of improvement increases when the value of threshold increases, this means that the ability of detector to detect, the results show when the threshold increases from (16) to (17), the ratio of improvement is equal to (17%), also when the threshold value is changed from (17) to (18), the ratio of improvement is equal to (22%), and from (16) to (22) the ratio of improvement becomes in the best case and gives the big enhancement of the performance. The selection of optimum transmitted power is considered very important, and it is limited to MAI problem during transition process. So it can be noticed in Figures (10, 11, 12, 13), the optimum power transmit gives the best performance, which leads to apply the ECC with good effective as in exploiting the transmission channel and the ability to correct, where it can be noticed the rate of improvement of SNR is equal to (23%) when changing the value of received power from (5) to (2) µw. The selection of suitable number of users is limited by power transmit. It can be noticed in Figures (14, 15, 16, 17) the increasing of the number users leads to increasing the average error with increasing the transmitted power. So by decreasing the transmitted power, the system performance will be improved. From results the improvement is conducted with decreasing the transmitted power where the ratio of improvement is equal to (23%) when changing the power from (5) to (2) µw, in entering the weight and threshold value it can be observed that the system performance is the best.

Figure (18) shows the average value of error at (N=10) for incorrect case equal to ($8*10^{-2}$) compared with the correct case (first polynomial) (255,247) which equal to (10^{-3}). Figure (19) shows the best performance compared with Figure (18) because of increasing the threshold value of detector to (22). In the other case when (w=5), threshold= (16, 22) as in Figures (20, 21), the system performance is given the best performance compared with that in Figure (18,19) for example at N=10 the BER=10^{-7} and $5*10^{-9}$. This appears the successful selection of system variables.

5. Conclusions

The proposed system shows enhancement in the performance of the data transition in the optical communication system by using OCDMA based on ECC technique. The optimum selection of variables leads to the ability of applying the ECC technique successfully to forms. So instead of additional correcting bits to enhance the performance of the system, where the improvement is accomplished by the optimum selecting of variable which in turn leads to optimum exploitation of the channel, thus the additional correcting bits become very effective and proportional with the average error results from the random interference, This shows the importance of the optical system design independently (without applying ECC), also this includes selecting the optimum values of variables for example, transmit power, code word length, code word weight and threshold value, where the selection of the better values gives a positive result which leads to the enhancement of the system performance, for this reason applying of ECC becomes very effective. The optimum selection for polynomial allow transmitting data at high rate, this is because of exploiting the channel capacity to transmit the information instead of correct bits, where the base of comparison is based on the balance between the range of utilization of additional correct bits and average of transmit information. This appears in the results, where the difference is observed using three types of polynomial based on correct bits and this is due to the system performance which must be acceptable and the ability to select the optimum value which allow transmitting a high data rate with maintaining the acceptable correct process where the ratio of improvement value is equal to (22%).

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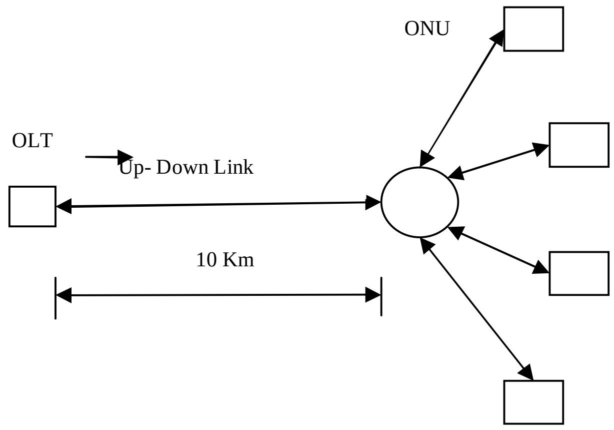


Figure (1) The topology of a PON with an optical line terminal (OLT), a passive splitter and several optical networking units (ONU)

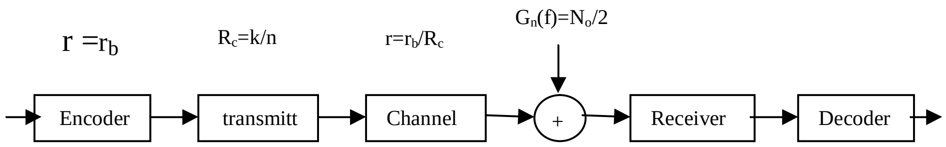


Figure (2) Block diagram of an FEC system

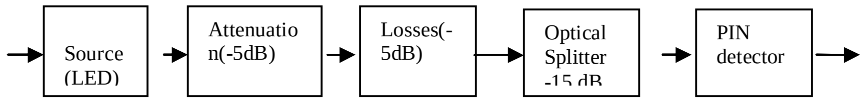


Figure (3) illustration of the model of losses in optical communication for star topology

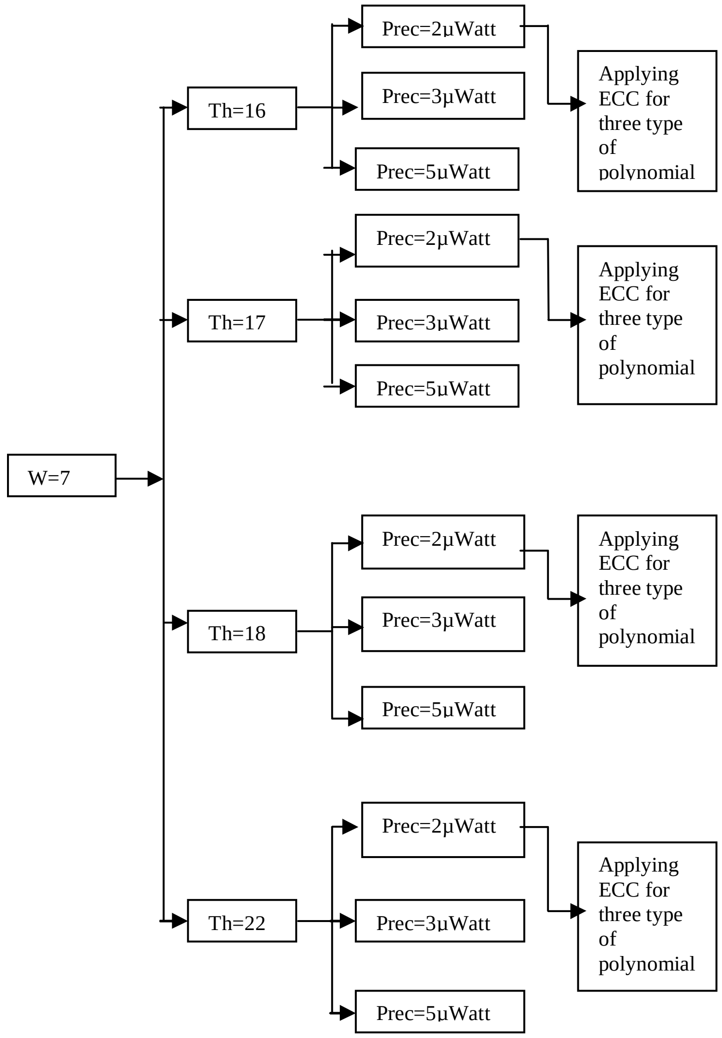


Figure (4) The flow chart of the research procedure (case one)

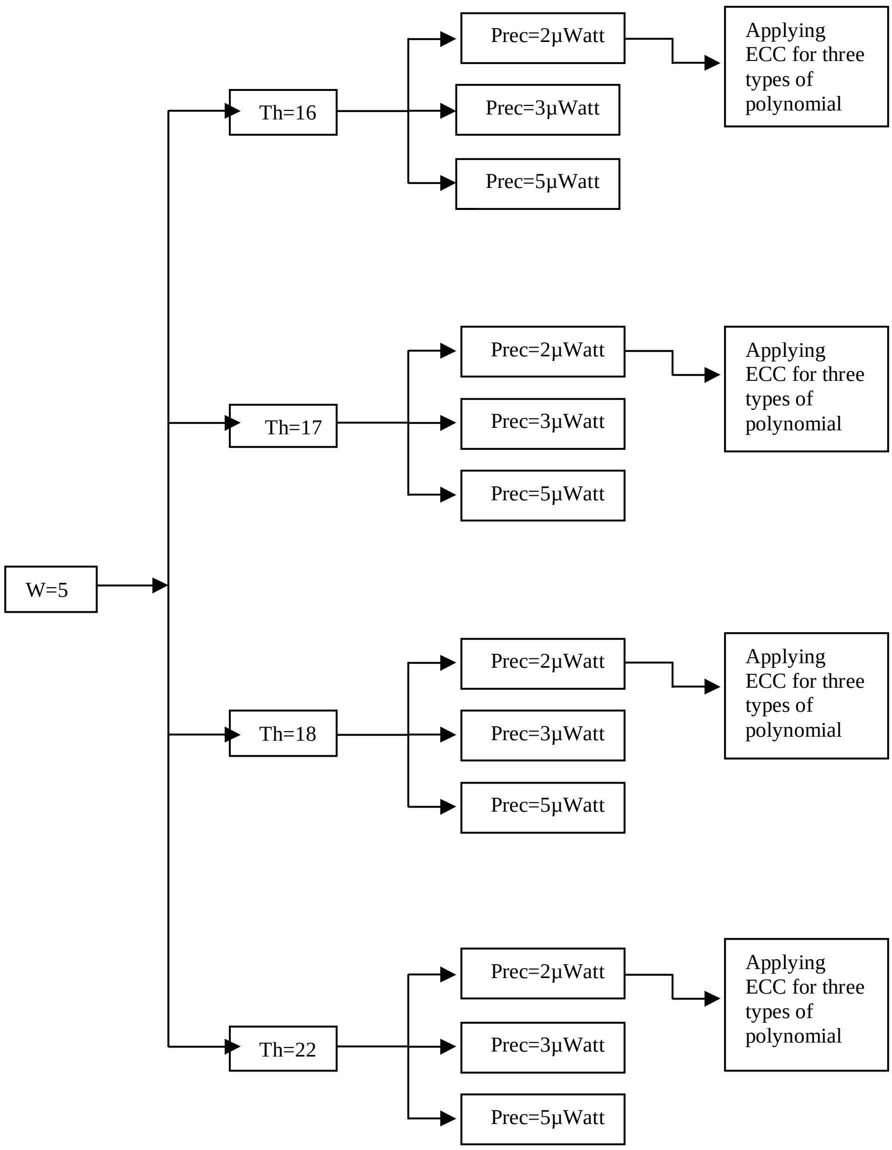


Figure (5) The flow chart of the research

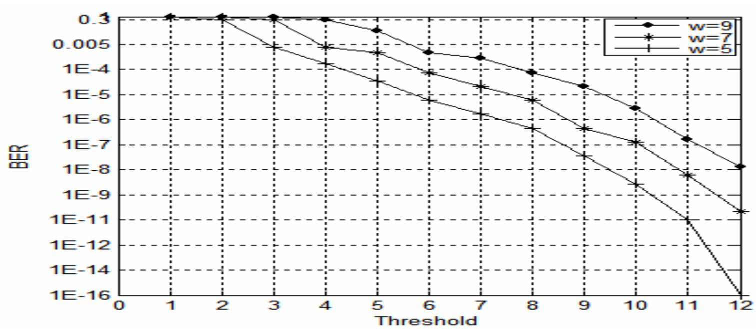


Figure (6) The relationship between threshold value and BER for three values of code word weight and (N=30).

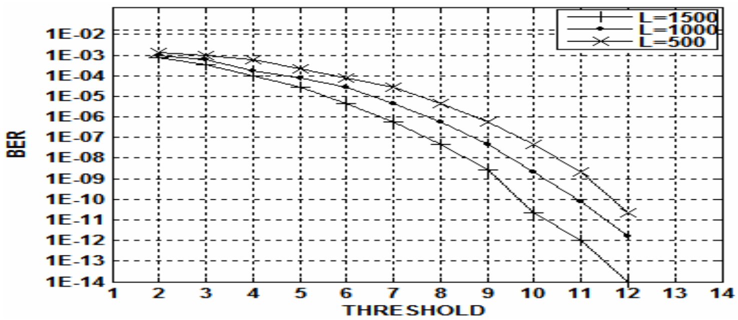


Figure (7) The relationship between thresholds and BER for three value of code word length (L) and (N=30)

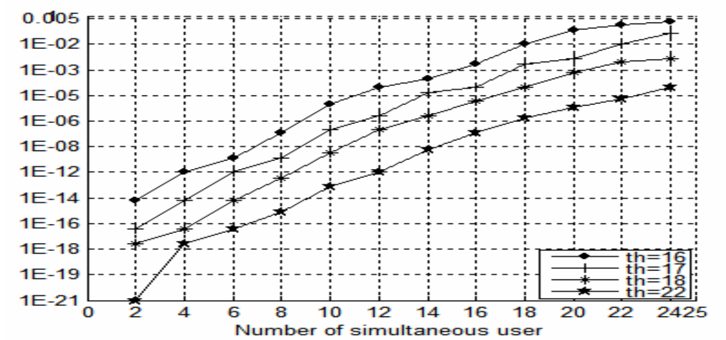


Figure (8) The relationship between the number of simultaneous users and BER for different values of threshold detector=7, L=1000

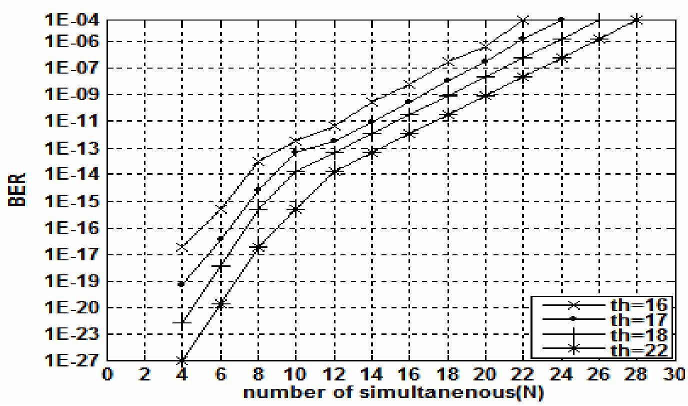


Figure (9) The relationship between numbers of user and BER for four value of threshold (μ), w=5, L=1000

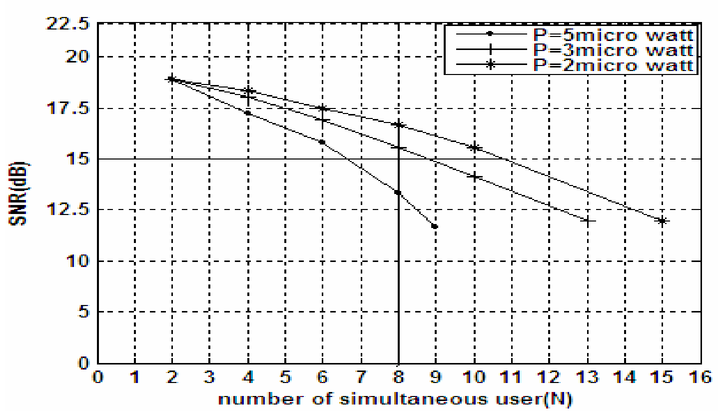


Figure (10) The relationship between number of simultaneous user and SNR (dB) for case (w=7), (μ=16)

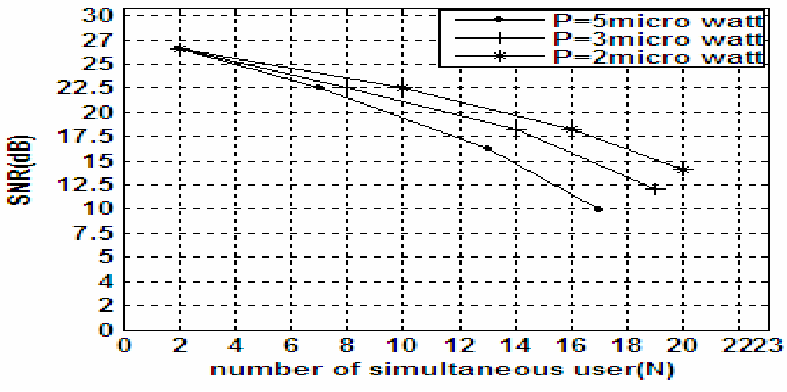


Figure (11) The relationship between number of simultaneous user and SNR (dB) for case (w=7),

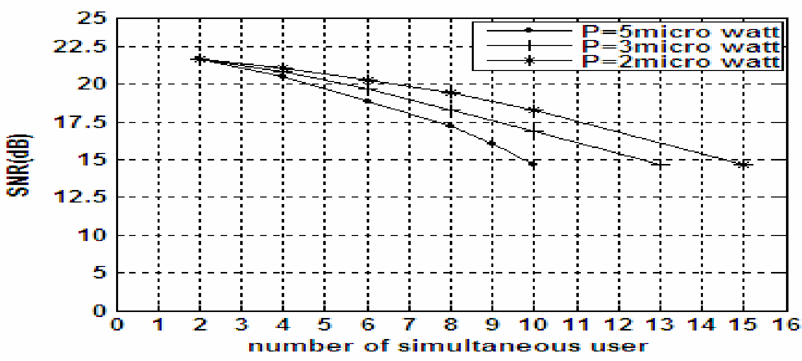


Figure (12) The relationship between number of simultaneous user and SNR (dB) for case (w=5),

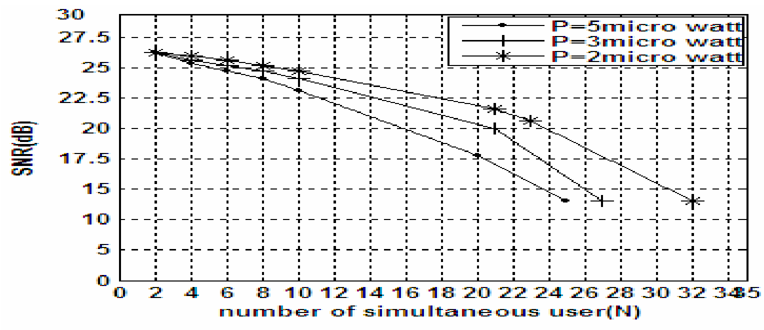


Figure (13) The relationship between number of simultaneous user and SNR (dB) for case (w=5),

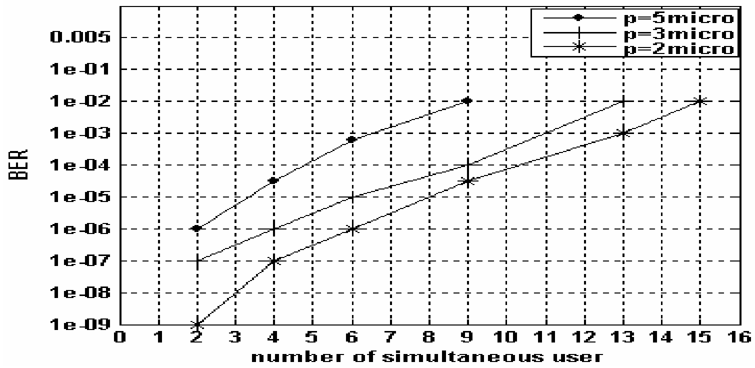


Figure (14) The relationship between number of simultaneous user and BER for case (w=7), (μ=16)

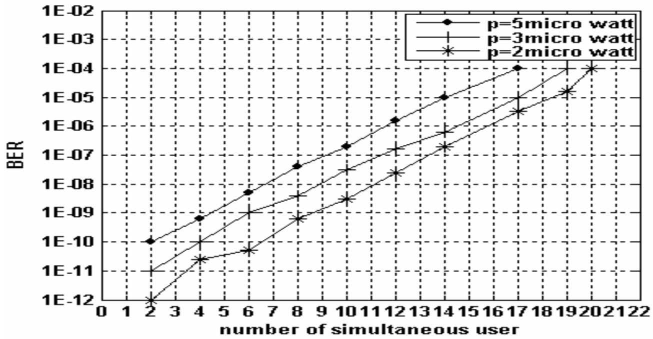


Figure (15) The relationship between number of simultaneous user and BER for case (w=7), (μ=22)

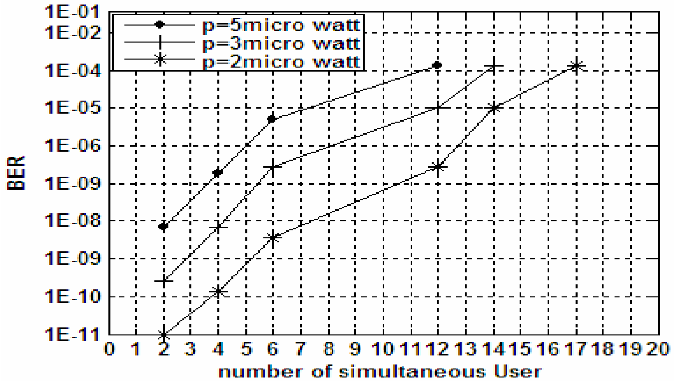


Figure (16) The relationship between number of simultaneous user and BER for case (w=5), (μ=16)

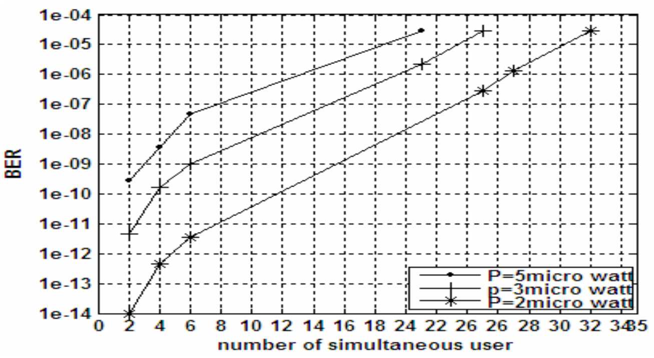


Figure (17) The relationship between number of simultaneous user and BER for case (w=5), (μ=22)

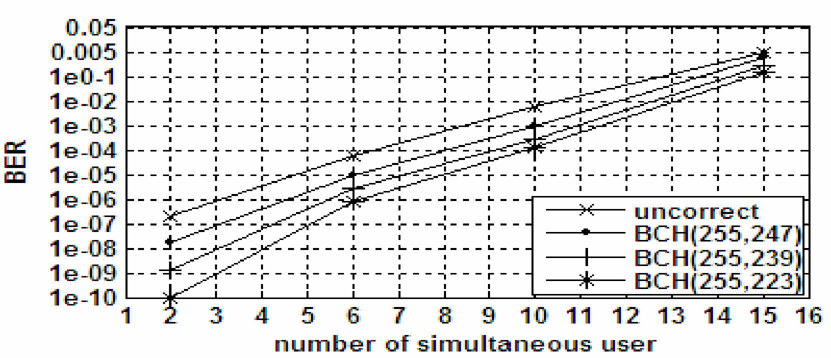


Figure (18) The relation between the number of simultaneous user and BER for the case (w=7, μ=16, Pres=2μw) for different BCH

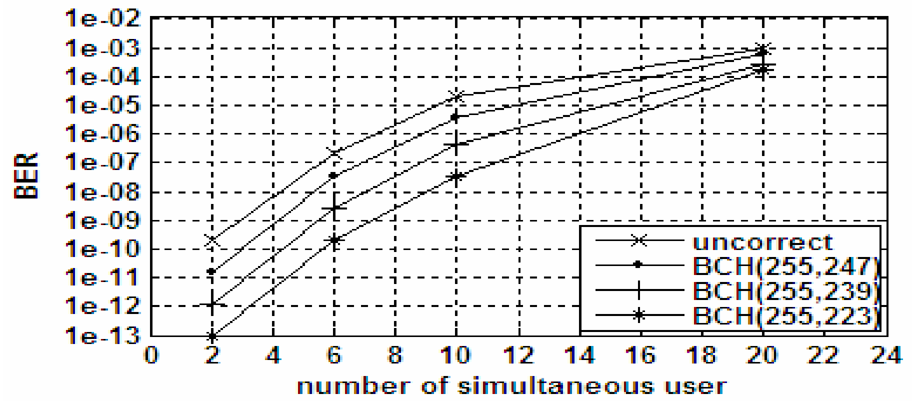


Figure (19) The relation between the number of simultaneous user and BER for the case (w=7, μ=22, Pres=2μw) for different BCH

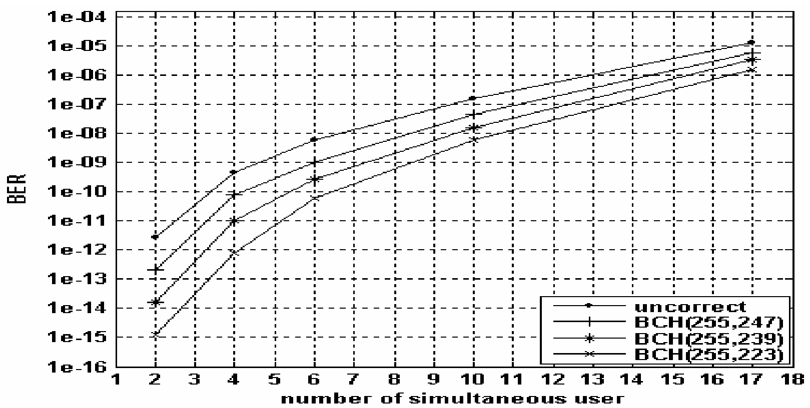


Figure (20) The relation between the number of simultaneous user and BER for the case (w=5, μ=16, Pres=2μw) for different BCH

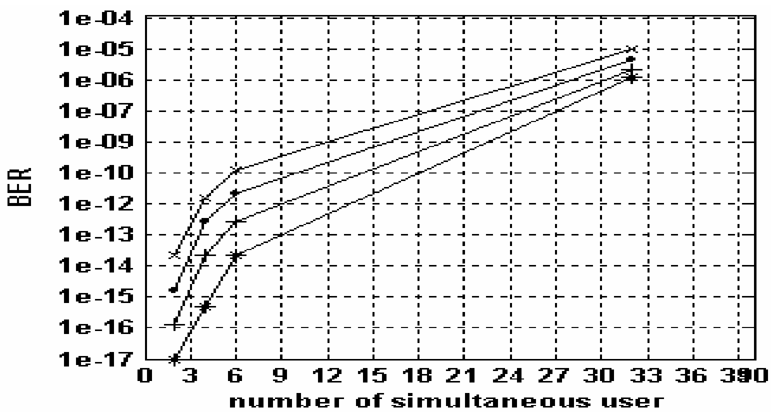
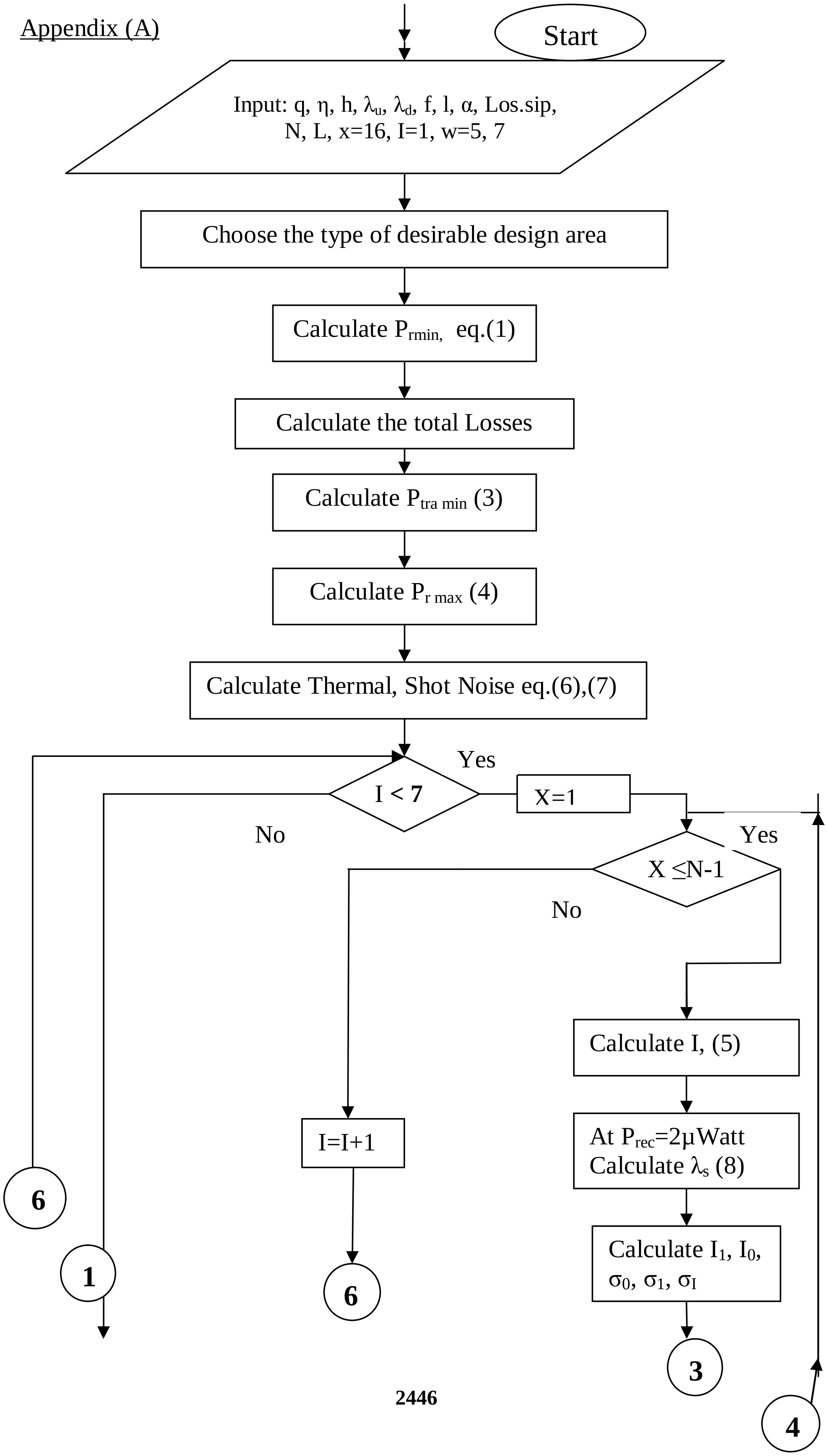
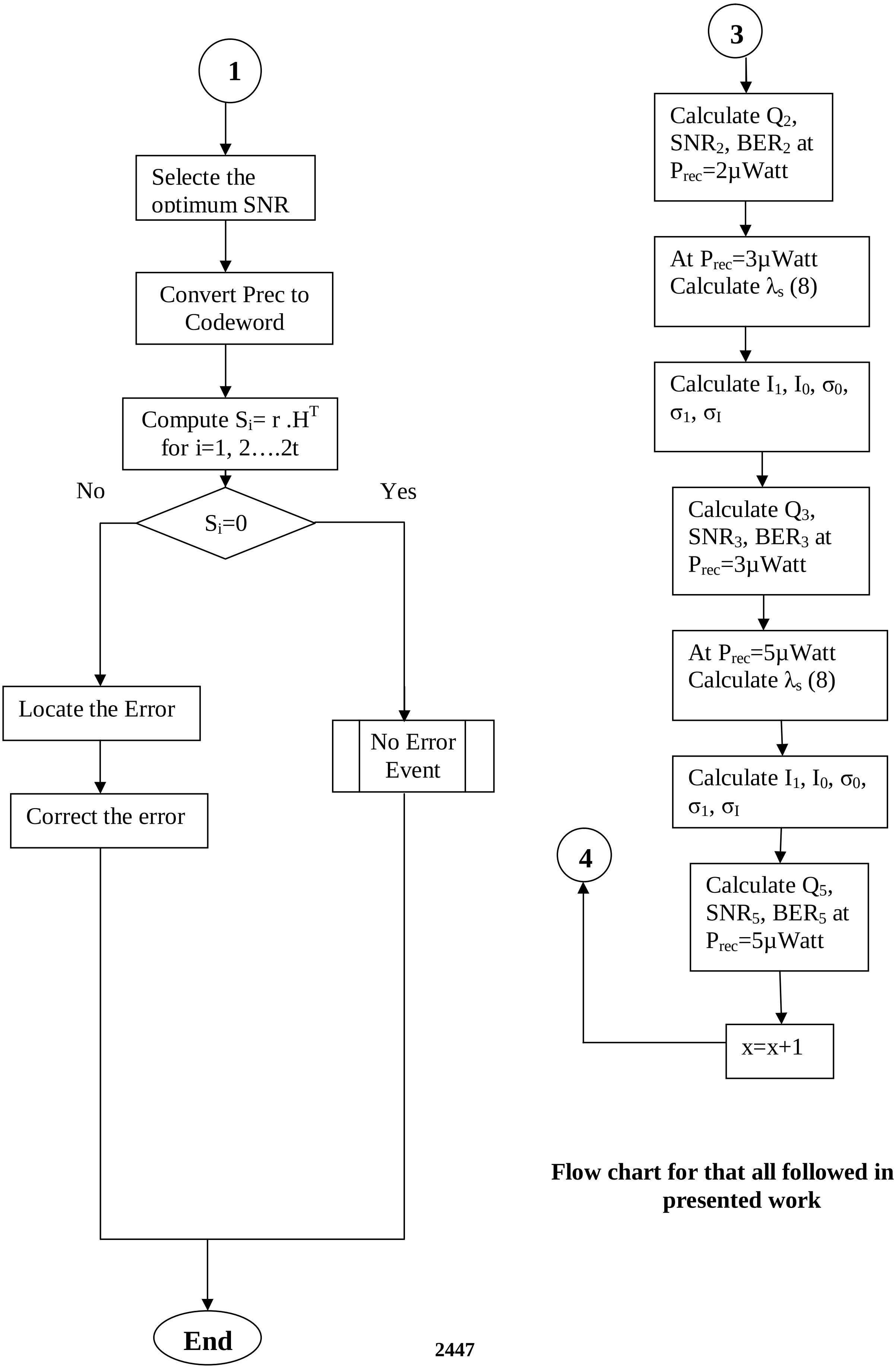


Figure (21) The relation between the number of simultaneous user and BER for the case (w=5, μ=22, Pres=2μw) for different BCH

Appendix (A)


Start
Input: q, η, h, λu, λd, f, l, α, Los.sip, N, L, x=16, I=1, w=5, 7
Choose the type of desirable design area
Calculate Prmin, eq.(1)
Calculate the total Losses
Calculate Ptra min (3)
Calculate Pr max (4)
Calculate Thermal, Shot Noise eq.(6),(7)
I < 7
Yes
No
X=1
X ≤N-1
Yes
No
Calculate I, (5)
At Prec=2μWatt
Calculate λs (8)
Calculate I1, I0,
σ0, σ1, σI
I=I+1
6
1
6
3
4



Flow chart for that all followed in the presented work