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NOVEL BIPOLAR RECONFIGURABLE CODE FOR OCDMA NETWORK

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Abstract. : *A novel bipolar code is proposed based on double weight code pattern with reconfigurable encoder design. The design of encoder and decoder reduces the complexity of system in bipolar domain. Reconfiguration of code at the transmitting end provides the code security against an eavesdropper at the transmitter and receiver ends .Complementary subtraction technique and Single photodiode detection technique is used to reconstruct the information and comparison also made in these techniques. The Result shows that the proposed method has better performance than the present EQC code bipolar and m-sequence code switching techniques.*

***Keywords**: Spectral Amplitude Coding (SAC), Multiple Access Interference (MAI), Bipolar code, Zero cross correlation (ZCC), Random Diagonal code (RD), Modified Quadratic Congruence code (MQC), Extended Quadratic Congruence (EQC).*

I. Introduction

The spectral amplitude coding (SAC) Optical code division multiple access (OCDMA) is prominence technique for asynchronous and synchronous transmission. In SAC OCDMA Multiple access interference exists due the ideal in phase cross correlation. That is, present between the codes assign to each user in unipolar (on) or bipolar mode (on-off). It should be the minimum as possible as, in SAC OCDMA [1-2]. RD, MQC and MDW technique offer the long length and ideal in phase unit and variable cross correlation [3-5].But these codes require the large channel bandwidth and narrow filter at the receiver end. Code interception at the transmitter can easily be done in unipolar code by observing the presence and absence of energy level [6-7]. So two code keying (Bipolar) pattern is formed this requires the large code length and complexity of the encoder and decoder increases [8],[10]. By implementing the desired filter at user transmitter end according to any one code (on or off code) spectrum, information can be extracted at each user's transmitting end. So avoiding the easiness in detection method a new double weight based bipolar code is developed. This code consist the smaller length and less complexity in decoder design compare to the present design [8,9]. Reconfiguration of two code keying is also performed at each user to boost the security against eavesdropping. Section II constructs the code design. Section III performed the mathematical analysis. Conclusion of work is mentioned at the end of the paper.

II. Proposed Methods:

The bipolar DW (Double weight) code shown in the table is defined for (N.W,λ_C) where N is code length , W weight and λ_C is the cross correlation between two users. Code is developed with the basic code of matrix of 3 users and code length of 4. Table.1 shows the code distribution.

The code is described in following points

(1) The code assigns to individual user in on-off mode does not contain the overlapping chip.

(2) Code assigns to on or off position for each user possess the ideal in phase unit cross correlation with another user's on or off position code.

(3) The Weight of two is maintained for reducing the code complexity.

Mapping technique is used for the large number of users

$$M_1 = \begin{bmatrix} M_0 & 0 \\ 0 & M_0 \end{bmatrix}$$

$$\text{Length of the code(N)} = \frac{4}{3} \times K \ldots\ldots (1)$$

K= number of users

Table.1 Code distributions between the users in bipolar mode (M_0)

	Bit		λ_1	λ_2	λ_3	λ_4
User1	1(on)	Code11	1	1	0	0
	0(off)	Code12	0	0	1	1
User2	1(on)	Code21	0	1	1	0
	0(off)	Code22	1	0	0	1
User3	1(on)	Code31	0	1	0	1
	0(off)	Code32	1	0	1	0

III.Encoder design

Coding spectrum is generated according to the above mention coding method and assigned to the each user's in on and off positions in a reconfigurable manner as shown fig1. Switch of $2 \times 2$is implemented to reconfigure the bipolar code of each user at the transmitter end.

At the decoding terminal ends single FBG is used to reconstruct the 1100 and 0011 (in case of user1) code based on complementary subtraction technique [11]and switch of smiler switching pattern as in transmitter ends, is applied to the receiver end.The Differential photodiode detection technique as in Fig 1 and single photodiode detection technique[12] as shown in Fig.2 is used to eliminate the problem of MAI. Table.2 shown the code transmission when different user transmit the 1 or 0 bits. Table.3 and Table.4 describe the complementry and single photodiode detection tecniques.

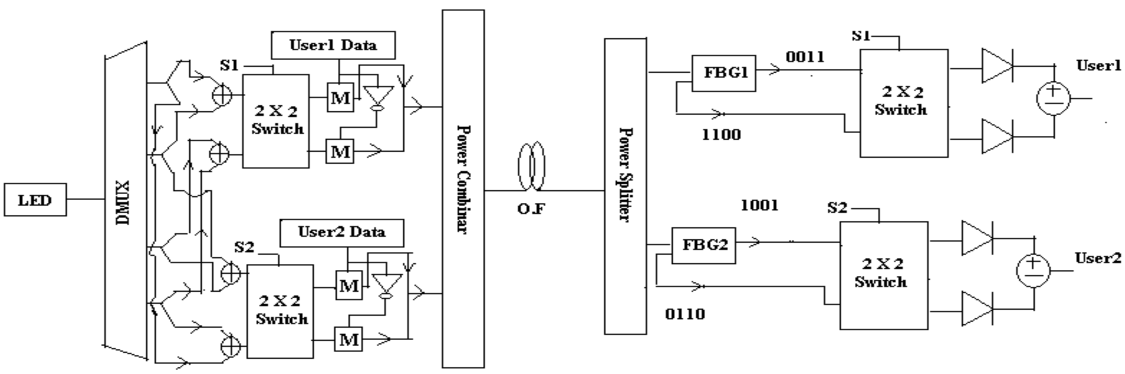


Fig 1.Encoder and decoder (complemantry subtraction)design of proposed Technique

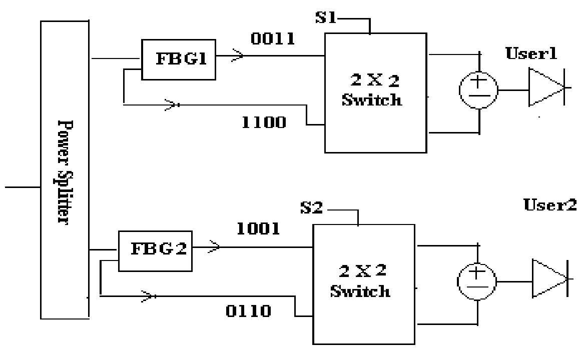


Fig 2.Decoder design of single photodiode detection

Table.2 code transmission in channel

User		λ_1	λ_2	λ_3	λ_4
1	On	1	1	0	0
2	Off	1	0	0	1
3	On	0	1	0	1

Table.3 Logical representation of interferance cancelation by complementry detection technique

	λ_1	λ_2	λ_3	λ_4
User1(X)	1	1	0	0
User2(Y)	1	0	0	1
$\overline{X}$	0	0	1	1

$\theta_{XY}=1$

$- \quad \theta_{XY}=1 \quad Z=\theta_{XY} - \theta_{XY}=0$

Table.4 Logical representation of interferance cancelation by SPD technique

Main User (DEC)	1 1 0 0
1st interfacing user (I_1)	1 0 0 1
2nd interfacing user(I_2)	0 1 0 1
($DEC.I_1$)	1 0 0 0
$\sum I_1 . DEC$	1
$\overline{DEC}$	0 0 1 1
($I_1.I_2$)	0 0 0 1
s-DEC=$\overline{DEC}$.($I_1.I_2$)	0 0 0 1
(I_1.s-DES)	0 0 0 1
$\sum (I_1 . s - DEC)$	1
$\sum (I_1 . DEC) - \sum (I_1 . s - DEC)$	1-1=0

Table.5 Code comparison

Code name	Weight	Number of users	Length of code	Cross-correlation
MDW	4	30	90	1
RD Code	5	30	35	Variable
MQC	7	30	49	1
MFH	7	30	42	1
Proposed code	2	30	40	1

IV Code detection technique

For analysis of this system we use the Gaussian approximation in our calculation (6,7). In this detection technique other than the thermal a noise (I_{th})and shot noise (I_{shot}), PIIN noise(I_{PIIN}) also present. The SNR for electrical signal is the average signal power to noise power SNR = [I^2/ σ^2].

$$\sigma^2 = I_{shot}^2 + I_{PIIN}^2 + I_{th}^2 \ldots\ldots (2)$$

$$\sigma^2 = 2eBI + I^2 B\, t_C + \frac{4K_b T_n}{R_L}$$

The following assumptions are made

(a) Each light source spectrum is flat over the bandwidth [Vo-ΔV/2 , Vo– ΔV/2]where Vo is central frequency and ΔV is the optical source bandwidth in Hertz.

(b) Each power spectral component has an identical spectral width.

(c) Each user has nearly equal power at the transmitter

(d) Each user bit stream is synchronized

At a time only one code(on or off) present corrosponding to the each user and this develop the ideal unity in phase cross correlation to another user .so two detection technique is used to recostruct the signal without MAI effect eaxplaing in the following.

(1) Substraction technique

$$\sum_{I=1}^{N} C_f(i)\, C_g\,(i) = \begin{cases} w; & k = l \\ 1; & k \neq l \end{cases} \ldots\ldots\ldots (3)$$

$$\sum_{I=1}^{N} \overline{C_f(\iota)} \left(C_g(i)\right) = \begin{cases} 1; & k = l \\ 1; & k \neq l \end{cases} \ldots\ldots\ldots (4)$$

From the SPD technique

$$\begin{Bmatrix} \sum_{i=1}^{N} C_f(i)\, C_g(i) - \\ \sum_{i=1}^{N} C_f(i)\,(C_f(i) C_g(i)) \end{Bmatrix} = \begin{cases} w-1; & k=l \\ 0; & k \neq l \end{cases} \dots\dots (5)$$

$$\langle \mathrm{I}^2 \rangle = 2\mathrm{eB}(\mathrm{I_{dd}}) + \frac{4\mathrm{K_b T_n B}}{\mathrm{R_L}}$$

In SPD technique

$$G(v) = \int_0^{\infty} \frac{P_{sr}}{\Delta v} \sum_{K=1}^{K} d_k \begin{bmatrix} \sum_{i=1}^{N} C_f(i)\, C_g(i) - \\ \sum_{i=1}^{N} C_f(i)\left(C_f(i) C_g(i)\right) \end{bmatrix} \left\{u\left[\frac{\Delta v}{N}\right]\right\} dv \dots (6)$$

$\sum_{K=1}^{K} d_k = w$ Than eq.4 can be simplified as:

$$= \frac{P_{sr} w}{N}[w+1] - \frac{P_{sr}}{N}[1+1]$$

$$= \frac{P_{sr} w}{N}[w+1] - \frac{P_{sr}}{N}[1+1]$$

$$\int_0^{\infty} G(v)\, dv = \frac{P_{sr} w}{N}(w-1)$$

Than total current is given as

$$I = \Re \frac{P_{sr} w}{N}(w-1) \dots \dots (7)$$

Shot noise power at receiver photodiode for SPD technique can be determined using

$$I_{shot}^2 = 2eB\Re \frac{P_{sr} w}{N}(w-1)$$

$$I_{PIIN}^2 = \Re^2 \left[\int_0^{\infty} G(v) dv\right]^2 B \frac{\int_0^{\infty} G(v)^2 dv}{\left[\int_0^{\infty} G(v) dv\right]^2 dv}$$

$$I_{PIIN}^2 = \Re^2 B \int_0^{\infty} G(v)^2 dv \dots \dots (8)$$

For SPD using a single PIIN $\int_0^{\infty} G(v)^2 dv$ is equal to:

$$= \frac{P_{sr}^2}{N\Delta v} \sum_{i=1}^{N} \left\{ C_f(i) \left[\sum_{K=1}^{K} d_f C_g(i)\right] \left[\sum_{m=1}^{K} d_m C_m(i)\right] \right\}$$

$$- \frac{P_{sr}^2}{N\Delta v} \sum_{i=1}^{N} \left\{ (C_m(i) C_n(i)) \left[\sum_{f=1}^{f} d_f C_m(i)\right] \left[\sum_{m=1}^{K} d_m C_m(i)\right] \right\}$$

$$= \frac{P_{sr}^2 w}{N\Delta v}\left[\frac{Kw}{N}\right] \sum_{f=1}^{f} \left[\sum_{i=1}^{N} C_f(i) C_g(i)\right] - \frac{P_{sr}^2 w}{N\Delta v}\left[\frac{Kw}{N}\right] \sum_{f=1}^{f} \left[\sum_{i=1}^{N} C_f(i)\left(C_f(i) C_g(i)\right)\right] \dots\dots (9)$$

Due to ideal in phase unit cross correlation property of code eq.6 become

$$= \frac{P_{sr}^2 w}{N\Delta v}\left[\frac{Kw}{N}\right][w+1] - \frac{P_{sr}^2 w}{N\Delta v}\left[\frac{Kw}{N}\right][1+1]$$

$$\int_0^{\infty} G(v)^2 dv = \frac{P_{sr}^2 K w^2}{N^2 \Delta v}(w-1)$$

Than PIIN power from eq.6 become

$$I_{PIIN}^2 = \frac{\Re^2 B P_{sr}^2 K w^2}{N^2 \Delta v}(w-1) \dots\dots (10)$$

Than SNR is given as considering the probability of sending '1 bit' is 1/2

$$SNR = \frac{\frac{\Re^2 P_{sr}^2 w^2}{N^2}(w-1)^2}{\frac{2eB\Re P_{sr} w}{N}(w-1) + \frac{\Re^2 B P_{sr}^2 K w^2}{2N^2 \Delta v}(w-1) + \frac{4K_b T_n B}{R_L}} \dots\dots (11)$$

In case of complementary detection technique

$$\sum_{i=1}^{N} C_k(i) C_l(i) = \begin{cases} w; & k=l \\ 1; & k \neq l \end{cases}$$

$$\sum_{i=1}^{N} \overline{C_f(i)}\; C_g(i) = \begin{cases} 1; & k=l \\ 1; & k \neq l \end{cases}$$

$$\begin{Bmatrix} \sum_{i=1}^{N} C_f(i)C_g(i) - \\ \sum_{i=1}^{N} \overline{C_f(i)}\, C_g(i) \end{Bmatrix} = \begin{cases} w-1; k=l \\ 0; \quad k \neq l \end{cases}$$

Power spectrum density during 1 bit period for upper and lower PIN diode is given as

$$G_1(v) = \frac{P_{sr}}{\Delta v}\sum_{f=1}^{g} d_k \left\{\sum_{i=1}^{N} C_f(i)C_g(i)\right\}\left\{u\left[\frac{\Delta v}{N}\right]\right\}$$

$$G_2(v) = \frac{P_{sr}}{\Delta v}\sum_{K=1}^{K} d_k \left\{\sum_{i=1}^{N} \overline{C_f(i)}C_g(i)\right\}\left\{u\left[\frac{\Delta v}{N}\right]\right\}$$

$$\int_0^\infty G_1(v)dv = \int_0^\infty \frac{P_{sr}}{\Delta v}\sum_{K=1}^{K} d_K \left\{\sum_{i=1}^{N} C_f(i)C_g(i)\right\}\left\{u\left[\frac{\Delta v}{N}\right]\right\} \mathrm{dv}$$

$$\int_0^\infty G_2(v)dv = \int_0^\infty \frac{P_{sr}}{\Delta v}\sum_{K=1}^{K} d_K \left\{\sum_{i=1}^{N} \overline{C_f(i)}C_g(i)\right\}\left\{u\left[\frac{\Delta v}{N}\right]\right\} dv$$

$$\int_0^\infty G_1(v)dv = \frac{P_{sr}w}{N}[w+1]$$

$$\int_0^\infty G_2(v)dv = \frac{P_{sr}w}{N}[1+1]$$

Total received current is given as

$$I = \Re\int_0^\infty G_1(v) - \Re\int_0^\infty G_2(v)$$

$$I = \frac{\Re P_{sr}w}{N}(w-1)$$

From equation 2 shot noise is given as

$$I_{shot}^2 = 2eB\left[\Re\int_0^\infty G_1(v)dv + \Re\int_0^\infty G_2(v)dv\right]$$

$$I_{shot}^2 = 2eB\Re\left[\frac{P_{sr}w}{N}(w+1) + \frac{P_{sr}w}{N}(1+1)\right]$$

$$I_{shot}^2 = 2eB\Re\frac{P_{sr}w}{N}(w+3) \ldots\ldots(12)$$

PIIN noise $I_{PIIN}^2 = \Re^2 B\left[\int_0^\infty G_1(v)^2dv + \int_0^\infty G_2(v)^2dv\right]$

$$\int_0^\infty \mathrm{G_1(v)^2dv \ and} \int_0^\infty \mathrm{G_2(v)^2dv \ \ can\ be\ written\ as:}$$

$$\int_0^\infty G_1(v)^2dv = \frac{P_{sr}^2}{N\Delta v}\sum_{i=1}^{N}\begin{Bmatrix} C_f(i)\left[\sum_{K=1}^{K} d_k C_g(i)\right] \\ \left[\sum_{m=1}^{K} d_m C_m(i)\right] \end{Bmatrix} dv$$

$$\int_0^\infty G_2(v)^2dv = \frac{\mathrm{P_{sr}^2}}{\mathrm{N\Delta v}}\sum_{\mathrm{i=1}}^{\mathrm{N}}\left\{\mathrm{C_l(i)}\left[\sum_{\mathrm{K=1}}^{\mathrm{K}} \mathrm{d_K\overline{C_f(i)}}\right]\left[\sum_{\mathrm{m=1}}^{\mathrm{K}} \mathrm{d_m C_m(i)}\right]\right\}\mathrm{dv}$$

$$\int_0^\infty \mathrm{G_1(v)^2dv} = \frac{\mathrm{P_{sr}^2 w}}{\mathrm{N\Delta v}}\left[\frac{\mathrm{Kw}}{\mathrm{N}}\right]\sum_{\mathrm{K=1}}^{\mathrm{K}}\left[\sum_{\mathrm{i=1}}^{\mathrm{N}} \mathrm{C_f(i)C_g(i)}\right]$$

$$\int_0^\infty \mathrm{G_2(v)^2dv} = \frac{\mathrm{P_{sr}^2 w}}{\mathrm{N\Delta v}}\left[\frac{\mathrm{Kw}}{\mathrm{N}}\right]\sum_{\mathrm{K=1}}^{\mathrm{K}}\left[\sum_{\mathrm{i=1}}^{\mathrm{N}} \overline{\mathrm{C_f(i)}}\ \ \mathrm{C_g(i)}\right]$$

$$\int_0^\infty \mathrm{G_1(v)^2dv} = \frac{\mathrm{P_{sr}^2 w}}{\mathrm{N\Delta v}}\left[\frac{\mathrm{kw}}{\mathrm{N}}\right][\mathrm{w}+1]$$

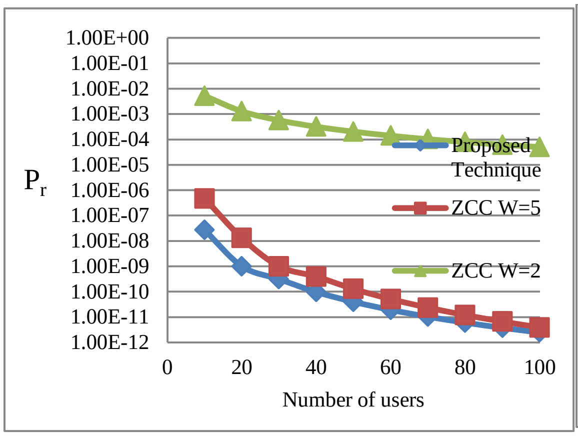
$$\int_0^\infty \mathrm{G_1(v)^2dv} = \frac{\mathrm{P_{sr}^2 w}}{\mathrm{N\Delta v}}\left[\frac{\mathrm{kw}}{\mathrm{N}}\right][1+1]$$

$$I_{PIIN}^2 = \Re^2 B\frac{P_{sr}^2 w}{N\Delta v}\left[\frac{Kw}{N}\right](w+3) \ldots\ldots(13)$$

$$SNR = \frac{\frac{\Re^2 P_{sr}^2 w^2}{N^2}(w-1)^2}{\frac{2eB\Re P_{sr}w}{N}(w+3) + \frac{\Re^2 B P_{sr}^2 K w^2}{2N^2\Delta v}(w+3) + \frac{4K_b T_n B}{R_L}} \ldots\ldots(14)$$

$$SNR = \frac{1}{2} erfc \sqrt{\frac{SNR}{8}} \ldots \ldots (15)$$

Typical parameters used in the calculation as below:
Photo detector quantum efficiency ($\Re$) 0.6
Line-width broadband source (ΔV) 3.75 THz
Operating wavelength (k_o) 1552 nm
Electrical bandwidth (B) 311 MHz
Data bit rate (R_b) 622 Mbps
Receiver noise temperature (T_n) 300 K
Receiver load resistor (R_L) 1030Ω
Code interception probability:
At Transmitter end the probability is give by $P_t = \frac{1}{2^n} \times \frac{1}{2}$
At Receiver end the probability is given by $p_r = \frac{1}{(2N_{C_2})} \times \frac{1}{(2N_{C_2}-1)} \times \frac{1}{2^n}$



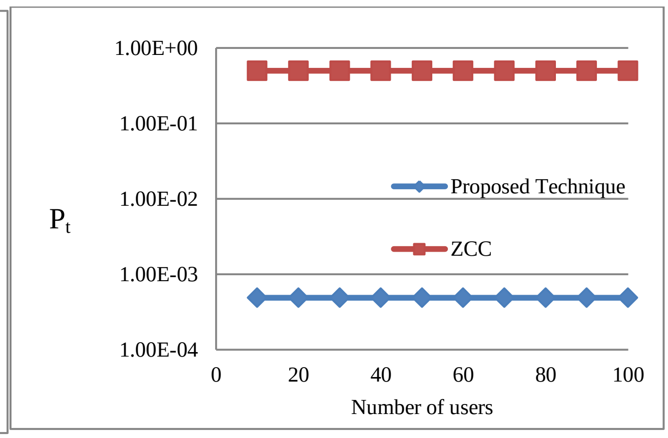


Fig 3 (a) Probability of code estimation at receiver ends   Fig 3(b) Probability of code estimation at transmitter ends

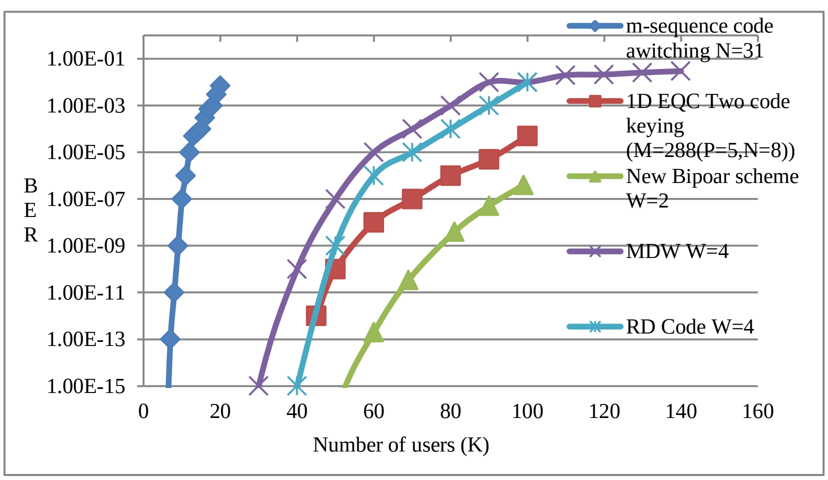


Fig4 A graph between the numbers of user Vs BER

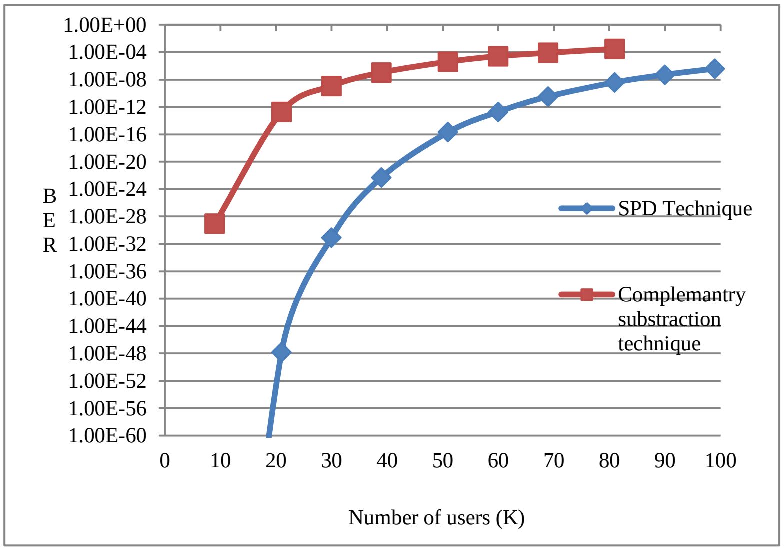


Fig5 A graph between the numbers of users Vs BER for two different detection methods

V. Performance Comparison

It is shown in fig.4 that the proposed two code keying method performance is better than the m-sequence method [9] and 1 D EQC two code keying method in term of number of user users versus Bit Error rate. The SNR is evaluated from equation 11 and 14. Table.5 shows the comparison of different coding technique. The proposed coding system has a smaller length of code with ideal in phase unit cross correlation. The design of the encoder and decoder is such that the code estimation probability for unauthorized user is very high at encoding and decoding end as shown in Fig.2 and Fig.3 and comparison is also done with present schemes. The decoder is constructed with two different approaches for improving the BER of information that is compared in fig.5 and this comparison show that the single photodiode detection technique is improves the performance in respect to the complementary subtraction technique. Results are analyzed with -10 dBm received power and at 622Mbits/s data rate.

Conclusion

In this paper new code is developed which implements in bipolar mode in reconfiguration pattern. Proposed Code can easily construct with smaller code length. Reconfiguration of code improves the code confidentiality against the eavesdropper which shows in analysis in this paper. The signal is detected with complementary subs traction and single photodiode detection technique. The complexity and cost of this design are very low. BER analysis is compared against the number of users for both methods. The result shows that The Single photodiode detection technique has a better performance.

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