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Effect of mixing parameter on deterministic joint remote state preparation of a qubit state via a Werner channel

A. Elkttaoui[α,*], **R. El guerbouz**[α,†] and **M. El baz**[α,‡]

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[α]Laboratoire de Physique Théorique, LPT-URAC 13, Faculté des Sciences, Université Mohamed V-Agdal, Av.Ibn Battouta, B.P 1014 Agdal Rabat, Morocco,

Abstract

In this paper, we study how the efficiency of deterministic joint remote state preparation (DJRSP) is affected, when qubits involved in the protocol are subjected to noise or decoherence. The study is performed on the DJRSP pattern, for its reliability, in a mixed GHZ state, mainly focusing on both phase flip noise and bit-flip noise, which are both found in pragmatic implementations of quantum communication protocols. Our study demonstrates that the fidelity of the output state for the phase-flip noise depends on the mixing parameter, the phase factor, the amplitude factor and the parameter for the phase-flip noise, while the precision depends only on the mixing parameter, the amplitude factor and the parameter for bit-flip noise. The receiver will get different output states depending on the result of measurement of the first party in the amplitude damping noise. Our results will be handy to improve the security of quantum communication in a pragmatic implementation.

Keywords: quantum communication, bit-flip noise, phase-flip noise, mixing parameter, deterministic joint remote state preparation

*abdelghafour.fsac@gmail.com
†rachid.elguerbouz93@gmail.com
‡moreagl@gmail.com

1 Introduction:

In the quantum realm, quantum entanglement is a necessity that has bewildering uses such as quantum teleportation[1], which can securely transmit a quantum state of a party at a remote receiver using entangled pre-shared resources. This is why there is room for research work on the quantum entangled states [2], such as quantum key distribution [3,4], quantum secure direct communication [5,6], quantum data hiding[7,8], quantum signature [9] and quantum authentication [10]. All these open new dimensions in security by-pass the limitations of the classical bit-wise implementations [11-16].
In the real world, the entangled resources are generated and transmitted by interacting with the external environment. These interactions are considered noise. In this context, many works have achieved quantum communication across noisy environments [17-20]. On the other hand, quantum algorithms, as Grover's search algorithm[21], can solve some problems much faster than classical algorithms [22-24]. Bennett et al. [25] demonstrated that an unknown quantum state can be teleported to a spatially separated place via the Einstein-Podolsky-Rosen channels. While if a quantum state is known to the sender, there is another way to transfer the quantum state without transmitting the qubit, which is known as remote state preparation (RSP) [26-28]. Thanks to shared quantum resources and additional standard information, the RSP can be performed with simpler measurements and classical communications, and costs less than quantum teleportation. Different types of RSP scheme were proposed, mainly the oblivious RSP [29], the continuous variable RSP [30], and RSP in Higher dimension space [31]. In recent years, many researchers have also proposed more complex patterns such as the Joint RSP (JRSP) [32-34], and the controlled RSP (CRSP) [35,36]. The difference between JRSP and CRSP is the roles of the preparators. In JRSP scheme, each transmitter is an information medium that holds partial information from a prepared state and all senders jointly prepare the state for a remote receiver. While in the CRSP there is a controller that does not know the details of the state, but the plan cannot be completed without his consent. Nonetheless, such schemes are not enough to secure sensitive information. Thats why Xiao et Al introduced the three-step strategy to increase the likelihood of success of JRSP, called, the deterministic JRSP (DJRSP). [37] By adding some classical communication and local operations, the probability of success of the preparation can be increased to 1. Nguyen et al. [39] presented two DJRSP schemes of a general state of one and two qubits using EPR pairs. Chen et al. [40] extended this idea to make a DJRSP of an arbitrary three-qubit state using six pairs of EPR.
In this paper we will study the influence of mixing parameter and noise rate, bit-flip and phase-flip, on DJRSP. We are focusing in this paper on one-qubit mixed GHZ based DJRSP scheme. Then, we compare the accuracy of the output stat with and without the mixing parameter.

2 Noisy DJRSP scheme of an arbitrary one-qubit state using shared GHZ mixed states

2.1 The noisy channels

We consider the effect of noise on the DJRSP process when the qubits suffer phase noise or bit-flip. The first noise action is described by a set of Kraus operators as follows:

$$\begin{aligned} E_0^{PF} &= \sqrt{1-\lambda}\ I \\ E_1^{PF} &= \sqrt{\lambda}\ \sigma_z \end{aligned} \tag{1}$$

where I is the identity matrix, σ_z is the Pauli matrix and $0 \leq \lambda \leq 1$ the probability of error. Similarly for bit-flip noise we use :

$$\begin{aligned} E_0^{BF} &= \sqrt{1-\lambda}\ I \\ E_1^{BF} &= \sqrt{\lambda}\ \sigma_x \end{aligned} \tag{2}$$

with $0 \leq \lambda \leq 1$ is the noise level and σ_x is the Pauli matrix.

2.2 DJRSP scheme of one-qubit based on GHZ mixed state

In DJRSP program, both Alice and Bob want to jointly prepare a state of qubit a xith the help of the supervisor Charlie. The state to be prepared is in the form :

$$|\Phi\rangle = a_0 e^{i\theta_0}|0\rangle + a_1 e^{i\theta_1}|1\rangle, \tag{3}$$

knowing that a_0,a_1 are real numbers known to Alice, and satisfying $a_0^2 + a_1^2 = 1$, also θ_0 , θ_1 are supposed known to Bob and satisfying the condition θ_0 , $\theta_1 \in [0, 2\pi]$.
As quantum resource that is shared between Alice, Bob and Charlie we use :

$$\rho_{ABC} = \eta|GHZ\rangle\langle GHZ| + \frac{1-\eta}{8}\ I \tag{4}$$

with $0 \leq \eta \leq 1$ the mixing parameter, and the GHZ state is given by $|GHZ\rangle = \frac{1}{\sqrt{2}}(|000\rangle + |111\rangle)_{ABC}$ (we suppose that the first qubit, A belongs to Alice, the second qubit, B belongs to Bob and that Charlie holds the last qubit C).
Now, the effect of noise described by (1) or (3) on the density operator is given by the expression:

$$\rho_{source} = \sum_{i,j} E_i^B E_j^C \rho_{ABC} (E_i^B)^+ (E_j^C)^+ \tag{5}$$

E_i,E_j Represent the noise operators that act on the different qubits and $i, j \in \{0, 1\}$.
It is assumed that Alice is the quantum resource generator, she keeps the qubit A and sends the qubits B and C to Bob and Charlie respectively through a noisy quantum channel of phase-flip noise or bit-flip.To simplify the analysis it is assumed that the noise of each channel is identical. Given these two noise environment, we show that the original mixed state becomes :

$$\begin{aligned} \rho_{source}^{PF} &= \frac{1}{8}\{(1+3\eta)|000\rangle\langle 000| + 4\eta(1-2\lambda)^2|111\rangle\langle 000| \\ &+ (1-\eta)|001\rangle\langle 001| + (1-\eta)|011\rangle\langle 011| + (1-\eta)|100\rangle\langle 100| \\ &+ (1-\eta)|101\rangle\langle 101| + (1-\eta)|110\rangle\langle 110| + 4\eta(1-2\lambda)^2|000\rangle\langle 111| \\ &+ (1+3\eta)|111\rangle\langle 111| + (1-\eta)|010\rangle\langle 010|\}. \end{aligned} \tag{6}$$

when afected by the phase flip noise.
Similarly when affected by bit-flip noise it be comes :

$$
\begin{aligned}
\rho^{BF}_{source} &= ((1-\eta 8+\frac{\eta}{2})(1-\lambda)^2+\frac{1}{4}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)|000\rangle\langle 000| \qquad (7)\\
&+ \frac{1}{2}\eta(1-\lambda)^2|111\rangle\langle 000|+\frac{1}{2}\eta(1-\lambda)\lambda|110\rangle\langle 001|+\frac{1}{2}\eta(1-\lambda)\lambda|101\rangle\langle 010|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|001\rangle\langle 001|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|010\rangle\langle 010|\\
&+ \frac{1}{2}\eta\lambda^2|100\rangle\langle 011|+\frac{1}{2}\eta\lambda^2|011\rangle\langle 100|+\frac{1}{2}\eta(1-\lambda)\lambda|001\rangle\langle 110+\frac{1}{2}\eta(1-\lambda)\lambda|010\rangle\langle 011|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|011\rangle\langle 011|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|100\rangle\langle 100|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|101\rangle\langle 101|\\
&+ (\frac{1}{8}(1-\eta)(1-\lambda)^2+\frac{1}{8}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)+(\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)\lambda)|110\rangle\langle 110|\\
&+ ((\frac{1-\eta}{8}+\frac{\eta}{2})(1-\lambda)^2+\frac{1}{4}(1-\eta)(1-\lambda)\lambda+\frac{1}{8}(1-\eta)\lambda^2)|111\rangle\langle 111|\\
&+ \frac{1}{2}\eta(1-\lambda)^2|000\rangle\langle 111|,
\end{aligned}
$$

Alice and Bob can do the appropriate action on their own qubits to recover the original state according to the results measured by Alice and Bob and Charlie.

The DJRSP can be represented as follows:

Step1: Alice first measures qubit A by using the measurement operator$\{A_m\}$ with $m \in \{0,1\}$. The system of (B, C) will become

$$\rho_1 = tr_A\left[\frac{A_m * \rho_{ABC} * A_m^\dagger}{tr(A_m * \rho_{ABC} * A_m^\dagger)}\right], \qquad (8)$$

where $A_m = |\mathrm{P}_m\rangle\langle \mathrm{P}_m|$ with P_m is projective measurement.

Step2: Bob measures qubit B by using the measurement operator $\{B_n^m\}$ with $m, n \in \{0,1\}$. The system of qubit C becomes

$$\rho_2 = tr_B\left[\frac{B_n^m * \rho_1 * (B_n^m)^\dagger}{tr(B_n^m * \rho_1 * (B_n^m)^\dagger)}\right] \qquad (9)$$

where $B_n^m = |\mathrm{O}_n^m\rangle\langle \mathrm{O}_n^m|$ with $|\mathrm{O}_n^m\rangle$ can be rewritten as, $|\mathrm{O}_n^m\rangle = V^m|\mathrm{n}\rangle$ so that
$V^m = \frac{1}{\sqrt{2}}\begin{pmatrix} e^{-i\theta_m} & e^{-i\theta_{1-m}} \\ (-1)^m e^{-i\theta_m} & (-1)^{1-m}e^{-i\theta_{1-m}}\end{pmatrix}$

Step3: Charlie recovers the prepared state by performing $R_n^{(m)}$, that is

$$\rho_{out} = R_n^{(m)} * \rho_2 * (R_n^{(m)})^\dagger \qquad (10)$$

where $\{R_0^{(0)} = I,\ \ R_1^{(0)} = \sigma_z,\ \ R_0^{(1)} = -\sigma_z\sigma_x,\ \ R_1^{(1)} = -\sigma_z\}$ denote the recovery operators.

The output state for the phase-flip noise, then is

$$\begin{aligned}\rho_{out}^{PF} &= (1+\eta(1-2a_1^2))|0\rangle\langle 0| + 2a_0a_1\eta(1-2\lambda)^2 e^{i(\theta_0-\theta_1)}|0\rangle\langle 1| \\ &+ 2a_0a_1\eta(1-2\lambda)^2 e^{-i(\theta_0-\theta_1)}|1\rangle\langle 0| + (1-\eta(1-2a_1^2))|1\rangle\langle 1|\end{aligned} \tag{11}$$

Similarly to bit-flip noise, we will get:

$$\begin{aligned}\rho_{out}^{BF} &= (1+\eta(1-2a_1^2))(1-\lambda)|0\rangle\langle 0| - 2a_0a_1\eta(\lambda-1)e^{i(\theta_0-\theta_1)}|0\rangle\langle 1| \\ &- 2a_0a_1\eta(\lambda-1)e^{-i(\theta_0-\theta_1)}|1\rangle\langle 0| + (-1+\eta(1-2a_1^2))(\lambda-1)|1\rangle\langle 1|\end{aligned} \tag{12}$$

2.3 The scheme fidelity

we calculate the fidelity to study how much the initial state [3] is different form the output state. the fidelity in our case is given by :

$$F = |\langle\phi|\rho_{out}|\phi\rangle| \tag{13}$$

According to equations (3) and (11), it is easy to obtain the fidelity for the phase-flip noise in the form

$$F^{PF} = \frac{1}{2}\{1+\eta(16\lambda a_1^2(\lambda-1)(1-a_1^2)+1)\} \tag{14}$$

The equation above shows that the fidelity F^{PF} depends on the mixing parameter η, the noise rate λ and the amplitude factor $a_1 = \sqrt{1-a_0^2}$.

The behaviour of F^{PF} as a function of λ and a_1 with different values of η are plotted in Figure 1:

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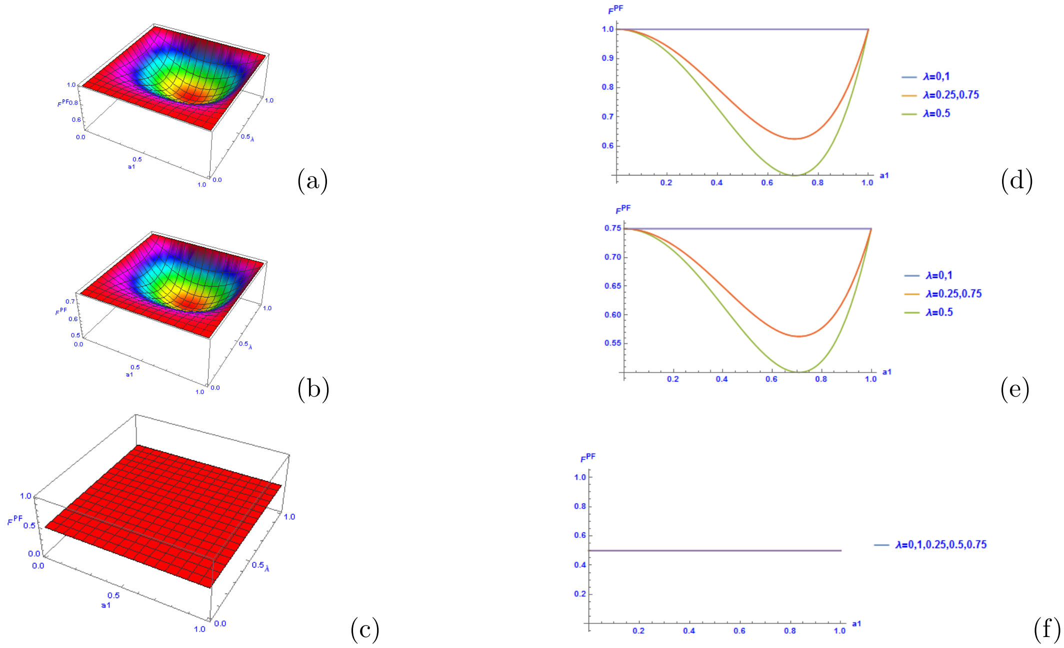

Figure 1 : The fidelity F^{PF} of the output state in the phase-flip noise with respect to a_1 and λ for different values of η. (a) F^{PF} with a_1 and λ when $\eta = 1$; (b) $\eta = 0.5$; (c) $\eta = 0$. (d) with a_1 for selected λ when $\eta = 1$; (e) $\eta = 0.5$; (f) $\eta = 0$.

The plots show that in case of a pure state $\eta = 1$, the maximum fidelity is 1. It is reached when $\lambda = 0$ or $1\ \forall a_1$ on one hand, on the other hand $a_1 = 0$ or $1\ \forall \lambda$. The minimum fidelity is 0.5 when $\lambda = \frac{1}{2}$ or $a_1 = \frac{1}{\sqrt{2}}$. Moreover λ takes other values different, then the fidelity is concave up, as shown in the figure 1 (d). In this case the state is pure and contains the maximum amount of quantum correlation.

For case of $\eta = 0.5$, which means that the GHZ state is mixed. The maximum value of fidelity is 0.75 and the minimum is 0.5. We see here that the maximum fidelity is decreased and the minimum is same.

For the last case $\eta = 0$, which means that the state is maximally mixed. It can be seen that the fidelity is stabilizing on the value 0.5 whatever the values of λ and a_1 are. This is expected as in this case, the state ρ_{source} doesn't include any quantum correlation, and the state preparation is entirely classical correlation.

Similarly, in the case of bit-flip noise using (3) and (12) we get for the fidelity the following expression

$$\begin{aligned} F^{BF} &= \frac{1}{2}\{(1-a_1^2)(1-\eta(2\lambda-1)) + a_1^4(1-\eta(2\lambda-1)) \\ &- 2a_1^2(1-a_1^2)(4\eta\lambda(\lambda-1)\cos(2(\theta_0-\theta_1) - (1+\eta-2\eta\lambda+4\eta\lambda^2))\} \end{aligned} \tag{15}$$

Here, the equation (15) of fidelity F^{BF} depends on η mixing parameter, λ noise rate, a_1 amplitude factor and also depends on θ_0 and θ_1 phase factors, which is different from the phase-flip noise. First, we plot the F^{BF} in terms of λ and a_1 with different values of η for $\theta_0 - \theta_1 = 0$ or π , as shown in the Figure 2.

Then, we plot the F^{BF} in terms λ and a_1 with different values of η for $\theta_0 - \theta_1 = \frac{\pi}{2}$ or $\frac{3\pi}{2}$, in Figure 3.

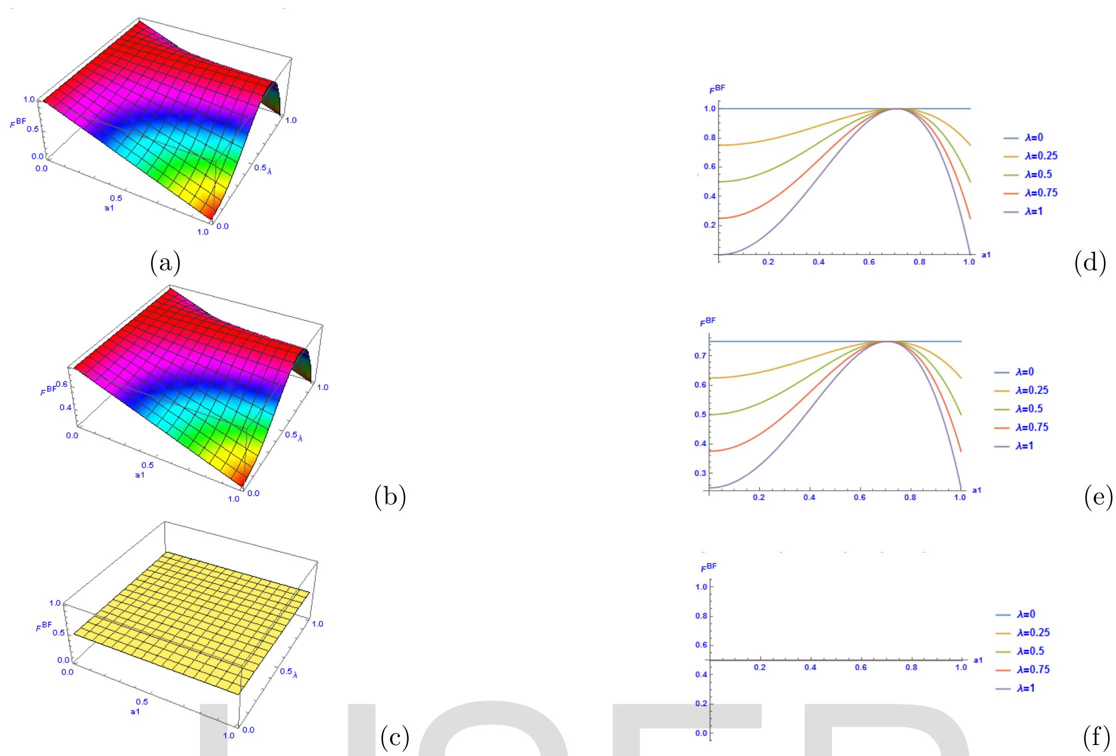

Figure 2 : The fidelity F^{BF} of the output state in the bit-flip noise with respect to a_1 and λ for different values of η and $\theta_0 - \theta_1 = 0$ or π . F^{BF} with a_1 and λ when (a) $\eta = 1$; (b) $\eta = 0.5$;(c) $\eta = 0$; F^{BF} With a_1 for selected values of λ when (d) $\eta = 1$; (e) $\eta = 0.5$; (f) $\eta = 0$.

Figure 2 shows that when $\eta = 1$, the maximum fidelity is 1, it is reached for $\lambda = 0 \ \forall a_1$, and for $a_1 = \frac{1}{\sqrt{2}} \ \forall\lambda$. The minimum fidelity is 0 reached for $a_1 = 0$ or 1, and $\lambda = 1$. When $\lambda \neq 0$ the fidelity is convex down, as show in the Figure 2 (d).
For the case where $\eta = 0.5$ the behaviour is similar as in the previous case ($\eta = 1$) except that the maximum value the fidelity reaches is 0.75 and the minimum is 0.25. So the maximum fidelity decreases and the minimum increases.

For the last case $\eta = 0$ corresponding to a maximally mixed state, it can be seen that the fidelity is stabilizing at the value 0.5 whatever values of λ and a_1 are.

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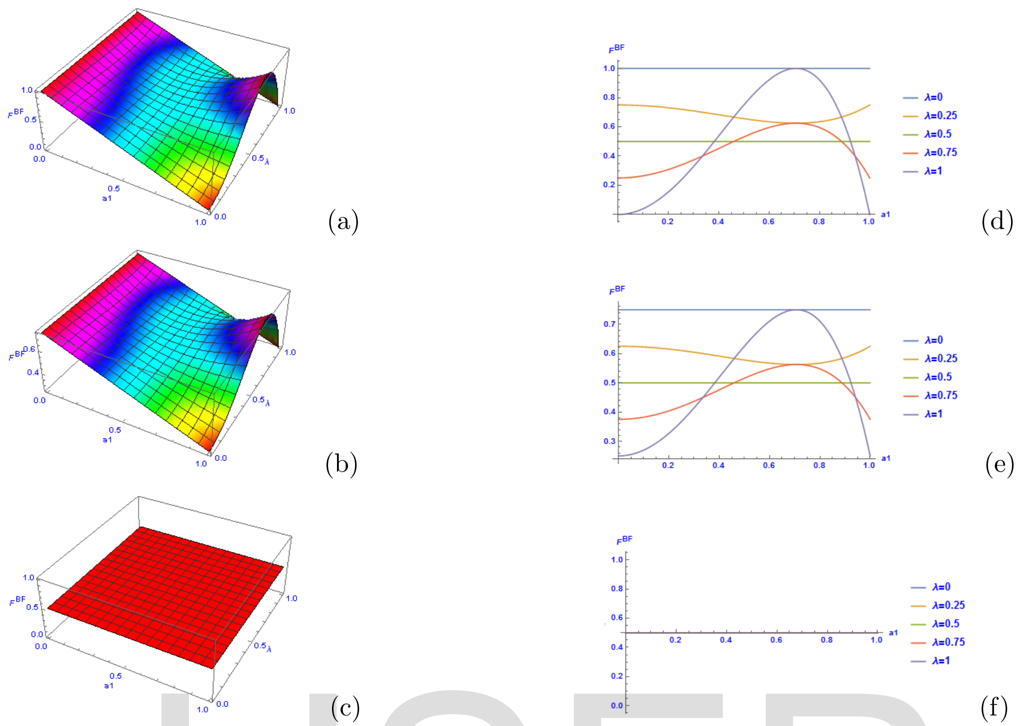

Figure 3 : The fidelity F^{BF} of the output state in the bit-flip noise with respect to a_1 and λ for different values of η and $\theta_0 - \theta_1 = \frac{\pi}{2}$ or $\frac{3\pi}{2}$. F^{BF} with a_1 and λ when (a) $\eta = 1$; (b) $\eta = 0.5$;(c) $\eta = 0.5$; F^{BF} With a_1 for selected of λ when (d) $\eta = 1$; (e) $\eta = 0.5$; (f) $\eta = 0$.

When $\theta_0 - \theta_1 = \frac{\pi}{2}$ or $\frac{3\pi}{2}$ Figure 3 show that the maximum and minimum value of fidelity remains the same, the only difference between this case and the previous case is that the fidelity in this case changes concavity at a certain value of λ. From the graph illustrated in Figure 4, we find that the critical value of λ at which this occurs is $\lambda = 0.5$.

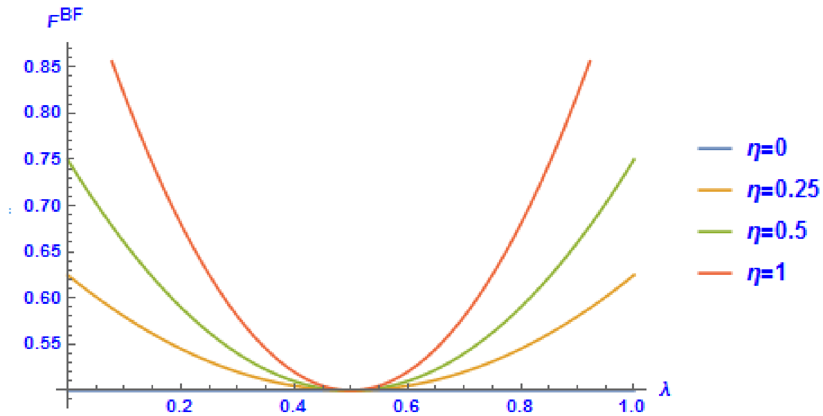

Figure 4 : The fidelity F^{BF} of the output state in the bit-flip noise with respect to λ for selected values of η when $\theta_0 - \theta_1 = \frac{\pi}{2}$ or $\frac{3\pi}{2}$.

3 Conclusion

In this paper we studied the influence of the mixing parameter η on the mixed GHZ state in the case of two types of noise phase-flip and bit-flip with the use of a DJRSP scheme. Some information about the prepared state is lost due to the noisy channel and also through the mixing effect. To describe the approximation of the final states with the original state and the amount of information lost in the process we used the fidelity. The result of our study show that the loss of the information in the case of a mixed GHZ state becomes important with respect to the pure state when approaching the reality by the reducing the mixing parameter η. In order to improve quantum communications theoretically and experimentally we must take into account the effect of the mixing parameter in the teleportation protocols of information because it contributes significantly to the loss of information.

References

[1] Zhang Z.J ,Liu,Y.M. Perfect teleportation of arbitrary n-qudit states using dierent quantum channels. Phys. Lett. A 372, 28 (2007).
[2] Rfifi S., EL Baz M. Effcient Schemes for Generating GHZ-Type, W-Type and Cluster ECS of n-Cavity Coherent Fields. Appl. Math. Inf. Sci. 9, No. 3, 1199-1203 (2015).
[3] Ekert, A.K. Quantum cryptography based on Bells theorem. Phys. Rev. Lett. 67, 661 (1991).
[4] Deng, F.G., Long, G.L.Controlled order rearrangement encryption for quantum key distribution. Phys. Rev. A 68, 042315 (2003).
[5] Deng, F.G., Long, G.L., Liu, X.S. Two-step quantum direct communication protocol using the EinsteinPodolskyRosen pair block. Phys. Rev. A 68, 042317 (2003).
[6] Wang, C., et al.Quantum secure direct communication with high-dimension quantum superdense coding. Phys. Rev. A 71, 044305 (2005).
[7] B.M. Terhal, D.P. DiVincenzo, D.W. Leung, Hiding bits in bell states, Phys. Rev. Lett. (2001), 86(25), 5807
[8] Z.G. Qu, X.B. Chen, X.J. Zhou, X.X. Niu, Y.X. Yang, Novel quantum steganography

with large payload, Opt. Commun. (2010), 283(23), 4782
[9] M.M. Wang, X.B. Chen, Y.X. Yang, A blind quantum signature protocol using the ghz states, Sci. China Phys. Mech. Astron. (2013), 56(9), 1636
[10] M. Curty, D.J. Santos, Quantum authentication of classical messages, Phys. Rev. A (2001), 64(6), 062309
[11] A. Shamir, How to share a secret, Commun. ACM (1979), 22(11), 612
[12] Z. Xia, X. Wang, X. Sun, B. Wang, Steganalysis of least signi-cant bit matching using multi-order dierences, Security and Communication Networks (2014), 7(8), 1283
[13]Z. Xia, X. Wang, X. Sun, Q. Liu, N. Xiong, Steganalysis of lsb matching using dierences between nonadjacent pixels, Multimed. Tools Appl. (2016), 75(4), 1947
[14]T. Ma, J. Zhou, M. Tang, Y. Tian, A. Al-Dhelaan, M. Al-Rodhaan, S. Lee, Social network and tag sources based augmenting collaborative recommender system, IEICE T. Inf. Syst. (2015), E98-D(4), 902
[15]P. Guo, J. Wang, B. Li, S. Lee, A variable threshold-value authentication architecture for wireless mesh networks, J. Internet Technol. (2014), 15(6), 929
[16] Y. Ren, J. Shen, J. Wang, J. Han, S. Lee, Mutual veriable provable data auditing in public cloud storage, J. Internet Technol. (2015), 16(2), 317
[17] L.K. Grover, Quantum mechanics helps in searching for a needle in a haystack, Phys. Rev. Lett. (1997), 79(2), 325
[18]Z. Xia, X. Wang, X. Sun, Q. Wang, A secure and dynamic multi-keyword ranked search scheme over encrypted cloud data, IEEE T. Parall. Distr. (2016), 27(2), 340
[19] Z. Fu, X. Sun, Q. Liu, L. Zhou, J. Shu, Achieving ecient cloud search services: Multi-keyword ranked search over encrypted cloud data supporting parallel computing, IEICE T. Commun. (2015), E98.B(1), 190
[20] Z. Fu, K. Ren, J. Shu, X. Sun, F. Huang, Enabling personalized search over encrypted outsourced data with eciency improvement, IEEE T. Parall. Distr. (2015)
[21]L.K. Grover, Quantum mechanics helps in searching for a needle in a haystack, Phys. Rev. Lett. (1997), 79(2), 325
[22] Z. Xia, X. Wang, X. Sun, Q. Wang, A secure and dynamic multi-keyword ranked search scheme over encrypted cloud data, IEEE T. Parall. Distr. (2016), 27(2), 340
[23]Z. Fu, X. Sun, Q. Liu, L. Zhou, J. Shu, Achieving ecient cloud search services: Multi-keyword ranked search over encrypted cloud data supporting parallel computing, IEICE T. Commun. (2015), E98.B(1), 190
[24] Z. Fu, K. Ren, J. Shu, X. Sun, F. Huang, Enabling personalized search over encrypted outsourced data with eciency improvement, IEEE T. Parall. Distr. (2015)
[25] Bennett, C.H., Brassard, G., Crepeau, C., Jozsa, R., Peres, A.,Wootters,W.K.: Teleporting an unknown quantum state via dual classical and EinsteinPodolskyRosen channels. Phys. Rev. Lett. 70(13), 18951899 (1993)
[26] Lo, H.K. Classical-communication cost in distributed quantum-information processing: a generalization of quantum-communication complexity. Phys. Rev. A 62(1), 012313 (2000)
[27]Pati, A.K. Minimum classical bit for remote preparation and measurement of a qubit. Phys. Rev. A 63(1), 1430214304 (2000)
[28] Bennett, C.H., DiVincenzo, D.P., Shor, P.W., Smolin, J.A., Terhal, B.M.,Wootters,W.K.: Remote state preparation. Phys. Rev. Lett. 87(7), 077902 (2001)
[29] Leung, D.W., Shor, P.W. Oblivious remote state preparation. Phys. Rev. Lett. 90(12), 127905 (2003)
[30] Kurucz, Z., Adam, P., Kis, Z., Janszky, J.: Continuous variable remote state preparation. Phys. Rev.A 72(5), 052315 (2005)
[31] Zeng, B., Zhang, P. Remote-state preparation in higher dimension and the parallelizable manifold Phys. Rev. A 65(2), 022316 (2002)
[32] Xia, Y., Song, J., Song, H.S. Multiparty remote state preparation. J. Phys. B At. Mol. Opt. Phys. 40(18), 37193724 (2007)

[33] Nguyen, B.A., Kim, J. Joint remote state preparation. J. Phys. B At. Mol. Opt. Phys. 41(9), 095501 (2008)
[34] Wang, M.M., Chen, X.B., Yang, Y.X. Deterministic joint remote preparation of an arbitrary two qubit state using the cluster state. Commun.Theor. Phys. 59(5), 568572 (2013)
[35] Luo, M.X., Chen, X.B., Ma, S.Y., Yang, Y.X., Hu, Z.M. Remote preparation of an arbitrary two-qubit state with three-party. Int. J. Theor. Phys. 49(6), 1262 (2010)
[36] Wang, Z.Y. Controlled remote preparation of a two-qubit state via an asymmetric quantum channel. Commun.Theor. Phys. 55(2), 244 (2011)
[37]X.Q. Xiao, J.M. Liu, G.H. Zeng, Joint remote state preparation of arbitrary two- and three-qubit states, J. Phys. B At. Mol. Opt. Phys. (2011), 44, 075501
[38]B.A. Nguyen, T.B. Cao, V.D. Nung, Deterministic joint remote state preparation, Phys. Lett. A (2011), 375(41), 35703573
[39] Q.Q. Chen, Y. Xia, J. Song, Deterministic joint remote preparation of an arbitrary three-qubit state via epr pairs, J. Phys. A Math. Theor. (2012), 45, 055303
[40]M.M. Wang, X.B. Chen, Y.X. Yang, Deterministic joint remote preparation of an arbitrary two-qubit state using the cluster state, Commun.Theor. Phys. (2013), 59(5), 568