Quantum Superposition in Harmonic Oscillator for Communication and Cryptography

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ABSTRACT

The specifics of the quantum particle are given by the Schrodinger equation. The D Broglie principle allows us to measure the particle's position or momentum. The particle's energy or time can be measured in the same way. As a result, particle energy can also be utilised for cryptography and communication. Maintaining the particle's features across a very long distance is challenging. However, the wave can go forward or be transmitted via the quantum particle media. Therefore, communication can be done via Quantum Wave. The states of the quantum particle are employed for qubits in quantum computation. Additionally, the qubit's range is constrained. If a Quantum Wave is employed, a Quantum Analog Signal or a Quantum Digital Signal will be produced in place of a quantum particle. The Quantum Superposition can play an efficient role here. By converting the analog signal to digital bits, more digital bits can be produced, depending on the transmitter and receiver specifications for Quantum Waves. In the study, three hypothesis are discussed. These hypotheses describe the nature of the Quantum Wave, Quantum Superposition and Quantum Relativity. Protocols for energy-based quantum signals are also proposed here. Additionally, the security of the transmitted Quantum Signal can be improved by using the Quantum Wave. The Hermite polynomial can be utilized to represent the Quantum Wave. Quantum cryptography is totally dependent on quantum mechanics, in contrast to classical encryption's growing computing complexity. The degeneracy property of the Quantum Signal also protects the signal's security. Through various techniques, the encryption and decryption of the quantum message signal are also proposed for a cryptography application.

Quantum Wave, Quantum Superposition, Quantum Relativity, Quantum Entanglement, Quantum Signal, Quantum Communication, Quantum Cryptography

Introduction

For the wireless communication, classical communication is improved from $0G$ to $5G$ and as the Future Generation communication module, $6G, 7G$ and $8G$ are also being investigated.Telephone System (AMTS), Norwegian for Offentlig Landmobil Telefoni (OLT), Public Land Mobile Telephony and Swedish abbreviation for Mobile telephony system Data (MTD) modules have been used till $0.5G$ communication. Later Nordisk Mobile Telephony (NTD), Advance Mobile Phone Service (AMPS) and Cellular Digital Packet Data have been used as the $1G$ communication technology. For $1G$ communication FDMA multiplexing was used. Next TDMA and CDMA were introduced for General Packet Radio Service (GPRS) and Enhanced Data rates for GSM Evolution or Enhanced GPRS (EDGE) with $2G$ communication modules. Further the voice data communication has been upgraded with the Voice, video and data communication in $3G$ communication, where CDMA based High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA) mudules were used. In $4G$ communication, MC-CDMA, OFAM multiplexing have been used for the Long Term Evolution (LTE), Ultra Mobile Broadband (UMB) and THE IEEE 802.16 (WiMAX) technologies to provide the internet service. Here IP-broadband, LAN, WAN and PAN standard have been introduced. For the $5G$ communication CDMA based World Wide Wireless Web (WWWW) and IPv6 are being used. Here the Dynamic Information access for wearable devices with AI based capabilities have been provided with communication. Later the investigation is going on for Air Fiber Technology based $6G$ communication, where downloads, uploads, super-fast broadband Internet, CCTV monitoring, multiple line telephones, video conferencing every telecommunications requirements will be resolved. In the $7G$ and $8G$ communication the standards and protocols for satellite to satellite communication system and for cellular to satellite system will be investigated for LEO, GEO satellites. But still the classical communication is not capable for physical encryption and very long range extra-terristial object communication, which can be solved in Quantum communication[1],[2].

The foundation of quantum communication is the Quantum Key Distribution (QKD). The lossy fibre is crucial to the photons' ability to travel. Even though two communicating parties create a key that is safe from eavesdroppers, they still need to rely on a third party to extend the communication's range[3]. The literature uses free space transmission or telecom fibre channels for quantum communication. The average signal strength is at the single photon level since the QKD is based on the single photon. In addition to the polarization-based encoding, the quantum coordinate systems rotate related to the velocity of the transmitter and receiver. Phase variation is also introduced by the mirrors and coatings[4].

Quantum entanglement can be used to solve the issue. However, the propagation in the quantum channel degrades the particle-based entanglement. Entanglement purification is necessary for large-scale implementation due to the inevitable noise. The photon is absorbed in the quantum communication channel for the photon-based teleportation. It takes a lot of photons to communicate in order to fix the problem. The entanglement states likewise deteriorate rapidly with the channel length. As a result, many pairs must be properly intertwined. The procedure is reliant on traditional communication[5]. Quantum communication also makes use of continuous variable systems that exploit the electromagnetic field's bosonic modes. For quantum cryptography, other hardware-based security mechanisms are also being researched[6].

The classical channel is used with quantum channel in parallel for the quantum cryptography[7]. The foundation of quantum information processing and QKD is Heisenberg's uncertainty principle and the quantum no-cloning theorem. QKD uses photon polarisation and adheres to the B84 protocol[8]. Passive devices are used to implement the BB84 parametric down-conversion based application. The BB84 signal states were passively generated using coherent light and a single photon source[9]. As an alternative to single photon based QKD, quantum continuous variable based quantum cryptography is also being investigated through the use of quantum teleportation of coherent states. Here, coherent states are communicated in a random distribution. Eavesdropping protection is offered by the no-cloning based protocol, which also lacks "non-classical" features[10].Single photon sources based on quantum dots are also investigated. It is possible to develop quantum and solid state information. Additionally implemented is the change of features through the use of several quantum photon sources[11–1718]

Using the wave characteristics of the quantum system to express the quantum states is challenging for quantum entanglement. Research in mathematics is currently struggling to determine the proper Schrodinger's equation for the entanglement. Quantum entanglement research is still being conducted today. Various protocols for quantum communication, quantum computation, and quantum cryptography can be researched based on quantum entanglement[19–23]. The quantum entanglement of a quantum harmonic oscillator is also studied in presence of an external electromagnetic field[24]. The Schrodinger's equation can be solved using the eigenvalue and eigenstates. Because of the time-dependent electromagnetic field, the harmonic oscillator for the quantum particle is always time-dependent. As a result, the Hamiltonian also depends on time. With the exception of the frequency parameter being time dependent, the Hamiltonian is identical to that of a simple harmonic oscillator. The quantum particle's energy and angular momentum change for such systems. Additionally, the electromagnetic field is classical. Each eigenstate undergoes a phase transformation that is dependent on time in order to solve Schrodinger's equation. The operator approach for the eigenstate representations can make use of the matrix[25].

Due to the uncertainty the accurate position measurement of a particle is challenging task. Hence the parameters can be measured from indirect measurement at the cost of momentum[26]. Harmonic oscillator is studied due to the importance of the system[27,28]. The generalized coherent states are also studied for the harmonic oscillator[29]. The time evaluation and the expectation values of the position and momentum operators are also studied[30]. Time independent Schrodinger's equation for harmonic oscillator[31].

The characteristics of wave particle duality are where quantum mechanics theory diverges from classical mechanics. Each quantum state's wave and particle attributes are obtained here. Both features can be applied to any experiment. A quantum state becomes entangled as a result of superposition on a quantum system. Cat States are created by superposing coherent quantum states. Spin, energy, spatial node, and polarisation for quantum entanglement are among the various characteristics of a quantum state that can be used for measurement[3233]. Cat states are created via quantum superposition of two quantum states using quantum optics. The amplitude, phase, and quadrature of the quantum wave or particle are used to characterise the quantum states. These states hold promise for quantum communication[34].

Photonic multiqubit states and their entanglement to produce multiqubit cat states are difficult to create. In several degrees of freedom, hyper-entanglement is employed in the solution. However, photonic sub-wavelength phase stability is a problem for the hyper-entanglement[35]. Fully controllable multiqubit quantum computation is still a challenge as the multiple particle entanglement is a question of quantum processor for quantum information processing[3637].

Results

A particle is described by the wave function $\Psi(x,t)$, which can be obtained by solving the Schrodinger equation represented by equation 1,

$$i\hbar\frac{d\Psi}{dt} = -\frac{\hbar^2}{2m}\frac{d^2\Psi}{dx^2} + V\Psi \tag{1}$$

By separating the variable,

$$\Psi(x,t) = \psi(x)\varphi(t) \tag{2}$$

$$\int_{-\infty}^{\infty} |A\Psi(x,t)|^2\, dx = 1 \tag{3}$$

where, the particle is represented by the the probability density function $|\Psi(x,t)|^2$ and A is a multiplicative factor. The equation 1 and equation 3 both are consistent. The equation 3 is the normalization equation. The Schrodinger equation conserve the normalization equation.

Quantum Wave Function In the Haronic Oscillator

For the harmonic oscillator the potential energy V is represented by,[38]

$$V = \frac{1}{2}m\omega^2 x^2 \tag{4}$$

The time dependent Schrodinger equation is represented by equation 5,

$$E\psi = -\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + \frac{1}{2}m\omega^2 x^2\psi \tag{5}$$

If,

$$\xi \equiv \sqrt{\frac{m\omega}{\hbar}}x \tag{6}$$

From equation 5 and equation 6,

$$\frac{d2\psi}{d\xi^2} = (\xi^2 - K)\psi \tag{7}$$

where,

$$K = \frac{2E}{\hbar\omega} \tag{8}$$

By modifying equation 7 for very large ξ,

$$\frac{d2\psi}{d\xi^2} \approx \xi^2\psi \tag{9}$$

By solving equation 9,

$$\psi(\xi) = h(\xi)e^{-\frac{\xi^2}{2}} \tag{10}$$

Where,

$$h(\xi) \approx\ C\sum\frac{1}{(\frac{j}{2})!}\xi^j \approx\ C\sum\frac{1}{j!}\xi^{2j} \approx Ce^{\xi^2} \tag{11}$$

$$K = (2n+1) \tag{12}$$

From equation 8 and equation 12,

$$E = (n + \frac{1}{2})\hbar\omega \tag{13}$$

For $n = 0, 1, 2...$

$$h(\xi) = H(\xi) \tag{14}$$

The $h(\xi)$ is the polynomial of degree n in ξ. This is called Hermite polynomials $\mathbb{H}(\xi)$ in equation 14.
By normalizing the stationary states for the harmonic oscillator is represented by,

$$\psi_n(x) = (\frac{m\omega}{\pi\hbar})^{\frac{1}{4}} \frac{1}{\sqrt{2^n n!}} H_n(\xi) e^{-\frac{\xi^2}{2}} \tag{15}$$

The equation 15 describes the wave function for quantum oscillator, which is completely different from classical oscillator wave. Here the energy is quantized and the probability of getting the particle outside classical range is not zero. Unlike classical counterpart, here the distribution is represented over an ensemble of identically prepared systems.

The wave function can carry the information of a quantum state. The energy of the state can be used to generate analog discrete signal. The equation 13 describes different energy levels. By generating different energy level $E(t)$ with respect to time an analog discrete signal can be generated. Based on $E(t)$ $\psi_n(x)$ can be generated with respect to time. The energy data n of the quantum particle is transferred by wave function. Thus instead of particle, the quantum wave function can be used to transmit the details of a quantum state by equation 15. This date can be recovered from the received wave function. The degree n of the Hermite polynomials will be the transmitted message signal. The quantum analog discrete message signal can be converted into quantum digital bits. For this method the number of the qubit will be increased and the number of qubits will be dependent on the quantum analog to digital converter.

As the complete signal is transferred in terms of the Hermite polynomials based quantum analog discrete signal, the security of the quantum system is increased. To increase the security several quantum encryption methods can be applied on the transmitting signal. The Hermite polynomials is used to the security purpose of the quantum analog discrete signal.

Representation of Quantum State in terms of Energy and relation with Degeneracy

The issue of the degeneracy of the energy levels is crucial when studying quantum-mechanical difficulties. This degeneracy is frequently linked to basic symmetry features of the Schrodinger equation, and the symmetry conditions pertaining to the rotation-reflection group and the group of permutations of identical particles have received a great deal of attention.

The energy-time uncertainty principle is represented by equation 16.

$$\triangle E \triangle t \geq \frac{\hbar}{2} \tag{16}$$

Where, $\triangle t$ is the time to take system fundamentally. The quantum measurement by using the energy of a particle is difficult. The $\triangle E$ should be moderate for small value. For the rapid change, the equation 16 is valid for large $\triangle E$ only. Which constraints the transmission speed of the quantum signal.

The energy of the state indicates that the quantum states in the bound systems are discrete. To create a complete set of commuting observables, each energy state is represented along with the eigenvalues of other observables. If a particular energy eigenvalue is present in more than one state, the system is said to be degenerate. However, according to classical mechanics, a constrained system might not have any distinct states. Consequently, it is insufficient to define degeneracy in terms of quantum and classical mechanics. A classical bound system is typically multi-periodic. Thus, when there are f degrees of freedom, it specifies that every variable of the system can be extended with fundamental frequencies $\nu_1, \nu_2 ... \nu_f$ using Fourier series. If all of these $\mho$ frequencies are incommensurable, the system is deemed nondegenerate. The system is referred to as g-fold degenerate if there are g relations among the frequencies that have the form of equation 17 with integer b_j.

The equation $d = (\mho - 1)$ is said to as completely degenerate. If the Hamiltonian can be represented as a function of action variables, then the separable multiply periodic system is degenerate. In this case, only a linear combination with integer coefficients allows the Hamiltonian to depend on some of these variables. Equation 17[39] states that a massively periodic system has some degeneracy if it is separable and its Hamilton-Jacobi equation is likewise separable in a continuous family of coordinate systems.

$$\sum_{j=1}^{\mho} b_j^k \nu_j = 1; \quad k = 1,...d \quad (1 \leq d \leq \mho - 1) \tag{17}$$

A system is said to be invariant under a group $\mathbb{G}$ with generators $\mathbb{H}_j$ if its Hamiltonian $\mathbb{H}$ is such. There is a continuous family of coordinate systems in which the Hamilton-Jacobi equation can be separated if there is only one coordinate system in which it can be separated. The form of the Hamiltonian is the same in coordinates q, p, and q', p' connected to each other by $\mathbb{X}_j$, according to the invariance requirement expressed in equation 18. Equations 19 and 20 give it its name and result in a separable Hamilton-Jacobi equation in the variables q, p. In the variables q' and p', it results in an equation that is separable in precisely the same manner. Consequently, the existence of the $\mathbb{X}_j$ establishes degeneracy if the global transformations corresponding to equations 19 and 20 are single valued. The argument proving degeneracy from separability is irrelevant if these changes have infinitely many values.In this case, the presence of this specific group does not lead to degeneracy. A somewhat modified argument demonstrates that degeneracy again occurs when these transformations have finitely numerous values, with the frequencies involved being rationally related rather than equal[39].

$$(\mathbb{H}, \mathbb{X}_j)PB = 0 \tag{18}$$

$$q' = q + \epsilon(\frac{d\mathbb{X}_j}{dp}) \tag{19}$$

$$p' = p - \epsilon(\frac{d\mathbb{X}_j}{dq}) \tag{20}$$

The presence of integrals of the equations of motion of the form of equation 21, where the g's and p's are the coordinates and conjugate momenta of the system, is the main subject of the transformation theory of classical dynamics. The integrals in this case are not clear functions of time t. A set of independent integrals $\mathbb{F}_1, \mathbb{F}_2, \mathbb{F}_r$ has been discovered. These transformations will form a group if the collection of integrals satisfies conditions as stated in equation 22, according to the Lie theory of continuous transformation groups. At most, the coefficients $\mathbb{C}_{xy}^g$ are functions of the total energy, but they can also be constants. Thus, the search for integrals that allow one to specify the group's constituents reduces the challenge of identifying the continuous groups of symmetry transformations infinitesimal of a given dynamical problem. It could be required to symmetrically represent the integrals in the p's and q's since the quantum-mechanical theory requires that they be represented by Hermitian operators. However, in this case, they only follow the standard commutation guidelines. The $\mathbb{F}$'s commutation with the Hamiltonian expresses their integral feature. For our purposes, this correspondence must be an algebraic equivalence in which the operator relations of equation 23 are satisfied by the commutators of the $\mathbb{F}$ operators. According to the Hamiltonian alone, the $\mathbb{C}$s in this case have to be constants or, at most, operators[40].

$$\mathbb{F}(q_1, q_2 ... q_b; p_1, p_2 ... p_b) = Constant \tag{21}$$

$$(\mathbb{F}_x, \mathbb{F}_y) = \sum \mathbb{C}_{xy}^g \mathbb{F}_g \tag{22}$$

$$(\mathbb{F}_x, \mathbb{F}_y) = i\hbar \sum \mathbb{C}_{xy}^g \mathbb{F}_g \tag{23}$$

Discussion

In the study, Quantum protocols are proposed in terms of algorithms for secure Quantum Encrypted Communication (QEC). Here, an encryption and a decryprion algorithm are represented with a new protocol for Quantum Communication. Here, the Quantum Identification Lock (QIL) based QEC is proposed, where the QIL is distinct for each user. As the Quantum Signal (QS), is described in terms of Analog QS or Digital QS, the upgraded communication is compatible with transmittimg an extended range of QS. As the upgraded proposed model can transmit complex QS, the proposed model requires more security. The encryption and decryption methods are also proposed here, which are purely Quantum model-based for the proposed Quntum Communiaction proptocol.

0.1 Hypothesis of Quantum Wave

1. Quantum Wave is a single-valued function, which can not be defined by any multivalued classical function or classical series equation.

2. A Quantum wave is a discrete signal, which depends on a distinct particle inside a Quantum System.
3. For a Quantum System, if there is more than one particle, that resides in the Quantum System, each particle has a distinct Quantum wave, which can be defined by distinct equations.

$$i\hbar\frac{d\Psi_{QS}}{dt} = -\frac{\hbar^2}{2}\frac{d^2(\Psi_1/m_1+\Psi_2/m_2+\Psi_3/m_3+...\Psi_n/m_j)}{dx^2}+V(\Psi_1+\Psi_2+\Psi_3+...\Psi_j) \tag{24}$$

4. Unlike classical randomess, which is a mix of probabilistic and deterministic nature separately, the Quantum randomness is not dependent on previouly selected random terms. Instead, the Quantum randomness is a combination of both properties based on the known parameters, and along with these, the Quantum randomness is none of these mentioned properties according to the unpredictability of transformation and degeneracy. The Quantum randomness is truly random.
5. Quantum state can be defined specially by the properties, which can be described as the virtue of the Quantum wave and which hold the sustainability of the Quantum wave. The ancestral properties, which is unable to define the integrity of either the Quantum wave or the Quantum state, can be a successor Quantum property, but will not endorse the Quantum foundations.

$$2\pi\hbar\nu\Psi = -\frac{\hbar^2}{2m}\frac{d^2\Psi}{dx^2}+V\Psi \tag{25}$$

$$\nu\Psi = -\frac{\hbar}{4\pi m}\frac{d^2\Psi}{dx^2}+\frac{V}{2\pi\hbar}\Psi \tag{26}$$

0.2 Hypothesis of Quantum Superposition

1. A Quantum System contains a set of Quantum particle, which set of particle is in an Energy Reference Frame related to the mentioned Quantum System.
2. Each Energy Reference Frame has a bounded energy band, which is dependent on the set of particles in that Quantum System.
3. After the superposition of Quantum particles, a completely different Quantum State is formed with a completely different Energy Reference Frame, which have a different energy band with respect to the unsuperposed particles and the unsuperposed Quantum States before superposition.

$$i\hbar\frac{d\Psi_S}{dt} = 2\pi\hbar\nu_S\Psi_S \tag{27}$$

4. After superposition, the superposed Quantum system behaves as a single particle Quantum system.

$$\frac{i}{2\pi}\frac{d\Psi_S}{dt} = \nu_S\Psi_S \tag{28}$$

5. After the superposition of Quantum particles, the superposed particles are in attraction, which is defined by some unknown equation.
6. After superposition the equation of the superposed Quantum State is defined by a combination of the equations of the unsuperposed particles by some unknown mathematical operation.

$$i\hbar\frac{d\Psi_S}{dt} = -\frac{\hbar^2}{2}\frac{d^2\{\Psi_1/m_1;\Psi_2/m_2;\Psi_3/m_3;...\Psi_n/m_j\}}{dx^2}+V\{\Psi_1;\Psi_2;\Psi_3;...\Psi_j\} \tag{29}$$

7. The particle which tries to get out of the superposed Energy Reference Frame, requires more energy to be out of the superposed Energy Reference Frame. Here the required energy will not be added later with the unsuperposed particle, after breaking out the superposition.

$$i\hbar\frac{d\{\Psi_S-(\Psi_1;\Psi_2;\Psi_3;...\Psi_j)\}}{dt} = 2\pi\hbar\{\nu_S\Psi_S-(\nu_1\Psi_1;\nu_2\Psi_2;\nu_3\Psi_3;...\nu_n\Psi_j)\} = Constant \quad Unused \quad Rdiated \quad Energy = \mathbb{E}_{\mathbb{R}} \tag{30}$$

$$2\pi\hbar\{\nu_S\Psi_S-(\nu_1\Psi_1;\nu_2\Psi_2;\nu_3\Psi_3;...\nu_n\Psi_j)\} = h\{\frac{\Psi_S}{\lambda_S}-(\frac{\Psi_1}{\lambda_1};\frac{\Psi_2}{\lambda_2};\frac{\Psi_3}{\lambda_3};...\frac{\Psi_n}{\lambda_j})\} = \mathbb{E}_{\mathbb{R}} = h\nu_{\mathbb{R}} = h\frac{1}{\lambda_{\mathbb{R}}} \tag{31}$$

0.3 Hypothesis of Quantum Relativity

1. A Quantum system is defined by a discrete Energy State, named as Energy Reference Frame.

2. Inside an Energy Reference Frame all of the Quantum rules are equally followed.

3. A Quantum System with a different Energy Reference Frame has a Relative Energey and is called a relative energy reference frame.

4. If a set of Quantum Systems in Relative Energy, contains Quantum particles in very high speed, then all of the Quantum Systems will be equally affected by a particular Potential Energy.

The equation 24, 25 and 26 represents the nature of the quantum wave. Here, the equation 27, 28, 29, 30 and 31 represents the nature of quantum superposition. The equation 30 and 31 are representing the Quantum Superposed-State Radiation Effect. The equation 31 represents the cause of absorption and radiation of energy, where different waves can be absorbed or radiated in quantum mechanical effects. Due to this, there are light and darkness in the creation and destruction in the cosmological effect.

Every quantum signal contains secure quantum information about the QIL of both of the transmitter and the receiver (i.e. QIL_{Tr} and QIL_{Re}). Each transceiver contains a unique QIL. Every quantum communication service user has the details of all of the available transceivers with the corresponding QILs and the corresponding user details. The QIL of the transmitter will be entangled with the QIL of the receiver. For each communication for a transceiver one QIL is always permanent. Every transceiver will generate signals for all of the registered QILs for the searching purpose. The quantum communication provider must use a certain value of n for the confirmation of the secure communication channel between the transmitter and the receiver. If n is different the communication device can not be confirmed. The device confirmation is achieved based on the degeneracy of the quantum signal. After the device confirmation both transceiver will set the value of frequency and QILs for further communication.

Once the communication is confirmed the transmitter and receiver can send the message signals. As the quantum signal is used for communication, due to the benefit of the degeneracy, several communication users can use a single frequency for communication.

Besides the communicated signal also contains information about the message signal. The message signal will be in the form of the energy E (i.e. $M(\tau) = E(\tau)$). The $M(\tau)$ can be converted to $m(\tau)$ by using equation 8. Here according to the equation, $E(\tau) = (m(\tau) + \frac{1}{2})\hbar\omega$ the message signal can be transmitted. Here the message signals $m(\tau)$ for the time τ is generated. Thus the message signal is a discrete analog or digita signal. The receiver will generate signals for several $m(\tau)$. According to the degeneracy principle, only same signals will be matched and other signals will be vanished. Thus the receiver will capture the message signal. The discrete analog message signal can be converted to digital signal, where the bits of the digital signal is dependent on the quantum analog to digital converter.

Methods

Protocols of QIL based Secure Quantum Communication and Cryptography

Algorithm 1 Protocol for generation and usage of Quantum Identification Lock

1: Each quantum device have a unique identification module. The module is named Quantum Identification Lock (QIL). The QIL of a device can not be changed or modified.
2: Every device an send signal to a receiver device by using the QIL of the receiver device.
3: The QIL of the transmitter device will generate a function with the QIL of the receiver device.
4: Based on the generated function of the transmitter device, the transmitting signal will be generated at the transmitter end.
5: The transmitting signal contains the information of the QIL of both of the transmitter and the receiver.
6: The receiver can capture the received signal if the signal has information about the QIL of the receiver.

The Algorithm 1 describes the protocol for the generation and usage of QIL. The QIL is a quantum solid state challenge. The QIL will be different for each quantum device (QD). A quantum device will be identified by a unique QIL to other device. Each device has two set of QIL. Inside the first set it contains its own QIL, while on the other set it contains QIL of other devices with which devices it is wishing to communicate. Each QD is a communication device, so it contains a transmitter and a receiver module. Before transmitting and receiving a QD will generate a quantum function (QF) with itself and the communicating QD with which it is trying to communicate. Now the QF will be used to generate the transmitting signal. On the other side the receiver continuously generates QF with all other existing QILs. Due to quantum degeneracy the receiver QD can only capture the signal which is generated for the receiver QD.

Algorithm 2 Protocol for public discussion between transmitter and receiver

1: Alice will send the signal which contains the QIL of both of Alice and Bob.
2: As the signal contains the QIL of Bob, he will be able to capture the signal. From the signal he will get information about the QIL of Alice.
3: Bob will send a signal, which also contains the QIL of both of Alice and Bob for confirmation.
4: As the signal contains the information about the QIL of Alice.
5: The QILs of Alice and Bob are finalized by Bob and Alice. Now they can communicate by using the final keys.

The Algorithm 2 represents the protocol for securing the communication between the transmitter and the receiver QD. Here Alice's QD generates and transmits a signal for Bob's QD. After capturing the signal by Bob's QD receiver, Bob's transmitter QD sends a signal to Alice's receiver QD for confirmation. As the transmitting signal contains QF which includes Alice's QIL, the signal will be captured by Alice's receiver QD. In the procedure different parameters will be set between both of Alices's and Bob's QDs. Those parameters are the final keys of the communication between Alice and Bob. Those parameters can be changes each times they communicate. After confirming the final key the communication is established between Alice and Bob.

Algorithm 3 Protocol of Quantum communication of signal based on message

1: The message is an analog discrete signal. Based on the message a signal will be generated for the communication.
2: The communicating signal will be transmitted by the transmitter.
3: The communicating signal will be received by the receiver.
4: From the received signal the message will be generated at the receiver end.

The Algorithm 3 represents the protocol of the quantum communication of the signal based message. Here the message is a quantum analog discrete signal, which have a particular value for each time. Based on the message signal the transmitting signal will be generated by a QD. After transmitting the signal the receiver QD of other device will receive and decode the signal, if for the receiver QD the signal have been generated. From the decoded signal, the message signal will be reconstructed at the receiver QD.

Algorithm 4 Protocol of Quantum cryptography over the quantum communication

1: The QIL of Alice and Bob is distributed to Bob and Alice.
2: Then transmitted signal does not contains the QIL of the Eve. Thus the signal can not be captured by Eve's receiver.
3: If the Eve transmits a signal along with Alice, then the transmitted signal of Alice will not be captured by Bob's receiver if the communication is already established between Bob and Eve. Bob have the freedom to select the transmitter, with whom he want to establish the communication (i.e. Alice or Eve).
4: Only if both of Alice and Bob include the QIL of Eve in their communicating signal, then there will be only one way that Eve can join the communication. At that condition Eve acn capture the signals of Alice and Bob. Besides Eve can send signal to alice and Bob.

The Algorithm 4 represents the protocol of quantum cryptograpgy over the quantum communication. As the transmitting end of the transmitter QD the signal is generated for the particular receiver QD, the signal can not be decoded by any third party. Here, if Alice's transmitter QD generates signal for the Bob's receiver QD, then it can not be decoded by eavesdropper Eve. If Eve's transmitter QD also sends signal along with the Alice's transmitter QD, then Bob has the freedom to establish the communication with either Eve or Alice. Only if, both of the Alice and Bob's transmitter QD includes the Eve's QIL while they are generating and receiving signals, then only Eve's QD interfere with the communication between Alice and Bob.

Protocols of Quantum Cryptography for Encryption and Decryption of the Message signals

The Algorithm 5 represents the protocol for Alice's key creation. The Algorithm 6 prepresents Bob's encryption and at last Algorithm 7 represents the Alice's decryption algorithm. Here, Alice is asking to Bob for an encrypted

Algorithm 5 Alice key creation

Require: QIL_s, QIL_r, ξ, $n \in \mathbb{N}$
Ensure: $\Psi_{n,(s,r)}(\xi) \in \mathbb{R}$
1: Set a natural number n
2: Generate ξ and calculate $\Psi_{n,(s,r)}(\xi) \in \mathbb{R}$
3: Alice's private Key is QIL_s; while the public key is $(\xi, \Psi_{n,s,r}(\xi))$

message signal. Alice made the privet and public key for the communication. Later, Bob uses Alice's generated key to encrypt the message, which is recovered by Alice after receiving the message signal.

Algorithm 6 Bob encryption algorithm

Require: ξ, $\Psi_{n,s,r}(\xi)$, $M(\tau) \in \mathbb{R}$
Ensure: $\Psi_{n,s,r}(\xi) \in \mathbb{R}$, QIL_s, n
1: Choose Alice's public key $(\xi, \Psi_{n,s,r}(\xi))$
2: Message $M(\tau)$ present as a numerical value
3: Generate $m(\tau)$ from $M(\tau)$
4: Calculate $\Psi_{n,r,s}$, $\Psi_{m(\tau),r}(\tau)$
5: Send to Alice $\Psi_{n,r,s}$, $\Psi_{m(\tau),r,s}(\tau)$

The Algorithm 5 represents a function $\Psi_{n,(s,r)}$, which is generated by a specific Hermite polynomial-based wave feature for a specific value of n in the harmonic oscillator. Here, ξ is the parameter of the function Ψ. ξ can be measured by using equation 6. The s and r is dependent on the QIL of the sender and the receiver. After ensuring n, s and r the Hermite polynomial based waveform is generated in the Quantum domain. Here, the major work is to inform the value of n to the receiver. Once completed, the receiver Bob can send the message to Alice.

Algorithm 7 Alice's decryption algorithm

Require: QIL_r, $\Psi_{n,r,s}$, $\Psi_{m(\tau),r,s}(\tau)$
Ensure: $M(\tau) \in \mathbb{R}$
1: Using QIL_s calculate $m(\tau)$ from $\Psi_{m(\tau),r,s}(\tau)$
2: Recover message $M(\tau)$ from $m(\tau)$

The Algorithm 6 represents the encryption of message signal Bob. Here, n is replaced by $m(\tau)$ for different energy levels, to generate a quantum analog signal. The $m(\tau)$ is produced from actual message signal $M(\tau)$. Now, the Ψ_n, r, s and $\Psi_{m(\tau),r,s}$ are the transmitting signal, which are generated by Bob, who is now a sender.

The Algorithm 7 represents the decryption of message signal by Alice. Here, Alice knows the QIL_r, which is represented by Bob. Now, Alice will get the message signal from Bob, from which Alice can recover the $m(\tau)$ and later the actual message $M(\tau)$. The degeneracy property protects the message signal in the quantum domain, from the eavesdropper Eve.

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