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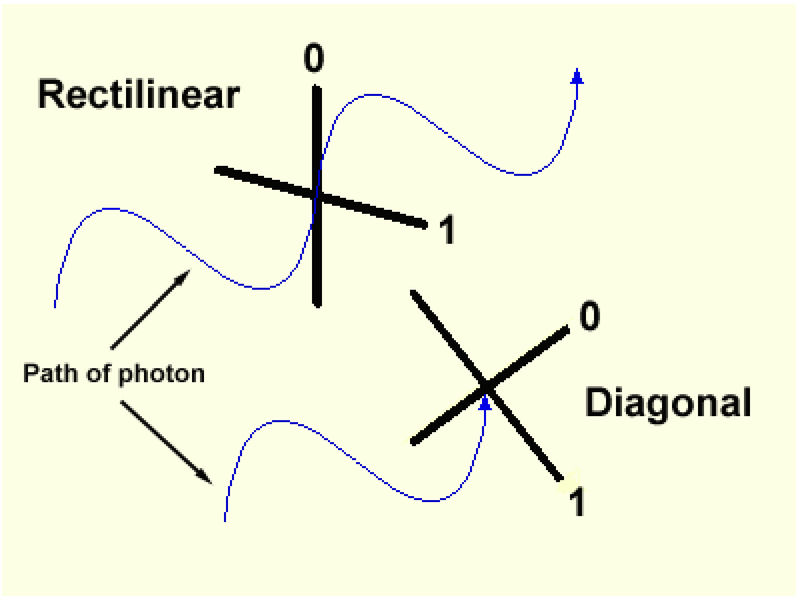
Quantum Communications

Since the beginning of time communication has always played a significant role in human kind's existence. From early grunts for coordinate hunting efforts, to smoke signals, and now to telephones and the internet mankind has always made and effort to use communications to better its existence. In the technology area, the speed at which information, or data, is transferred is the key to building more robust and responsive software and computer systems. With the invention of the internet, a worldwide communications platform was created. Now, with the internet in most businesses and many households around the world, a need to make the internet convenient and mobile surfaced. Many different forms of wireless data transfers have been created. WiFi, satellite, and microwave were all created in the quest for a wireless data transfer method that is just as fast as its wired counterpart. The next wireless method in the evolution of data communications is Quantum Communications.

Quantum communications is based on quantum physics. Quantum physics began with the discovery of the electron by J.J. Thompson in 1897 and is the study of extremely small particles. Quantum physics deals with electrons, protons, neutrons, and the particles that make up all of the above. Quantum physics is the basis of particle physics, condensed matter physics, and is now the basis for quantum communications. Quantum communications is based on the idea that information can be encoded as the polarization of photons. Einstein once stated in his theory of relativity that the closer the speed of light a body, object, or particle travels, the slower the body's internal clock passes. Since photons are the speed of light, then this method of transferring data should be the fastest ever conceived. The data itself will depend on the photon's oscillation. If the photon oscillates in one direction it can interpreted as a 0, if the photon oscillates in another direction it can be interpreted as a 1. Ones and zeros are the basis for binary data so in theory, data can be transferred via photon oscillation. A diagram of this method is illustrated in figure 1

Figure 1

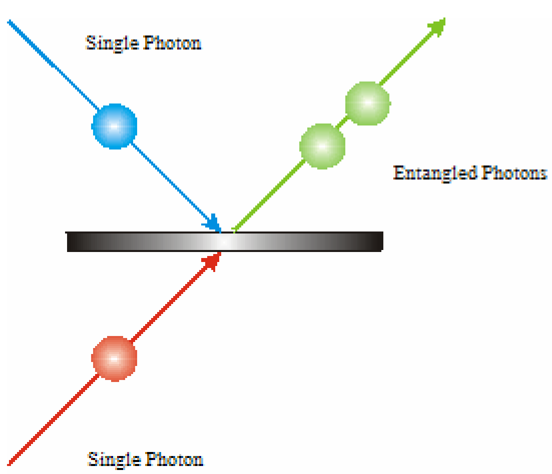


The two directions used in quantum communications are rectilinear and diagonal. The principle by which the data is communicated is in order to receive the correct information, the sender and the receiver must communicate via the same photon oscillation, either rectilinear or diagonal. If the data is sent via photon on a different oscillation than received, the result is the data is totally random and unidentifiable. Using this principle, a method exists by which data can be transferred using quantum communications that will prevent unwanted interception of the data. The sender can intentionally send data on a different oscillation than the data is meant to be received; therefore, anyone trying to intercept the data would not be able to interpret the result. The sender can then inform the receiver, using a more private means, of the polarizations that were used over the public channel.

A more advanced theory exists that would increase the amount of data that can be transmitted via quantum communication. This theory uses pair photon and two quantum gates known as "*U*" and "*M*". The sender of data would create two particles, or photons, in what is known as an entangled state. The sender would then perform one of four unitary functions on the pair of entangled photons and send one of the photons to the receiver through the quantum gate of *U*. The other bit, known as the "reference bit", is kept by the sender. The receiver of the photon would interpret the direction in which it is received and then communicate to the sender through the quantum gate of *M* to compare the received photon to the reference photon. Once the comparison of the entangled photons is made, the receiver can interpret which of the four actions was preformed on the pair. The comparison is known as a Bell Measurement. A Bell Measurement is the joint quantum mechanical measurement of two quantum bits, known as qubits. This determines which of the four of the Bell States, or photon entanglement states, the pair of qubits is in.

With these two theories exists a third theory that has to do with the networking of quantum communication to more than two nodes without taking the qubits out of the quantum state. The theory is that if a state that is being teleported is entangled with another state at the time, the entanglement as a whole is teleported and can be measured by a node. To illustrate this there will be three nodes named “Node A”, “Node B”, and “Node C”. Node A has one particle, Node B, being the middle node in the communication, has two particles, and Node C has one particle. Node A’s one particle is entangled with one of Node B’s particles. Node B’s other particle is entangled with Node C’s one particle. If Node B performs a Bell Measurement on its two particles it sends them into a Bell State, or state of entanglement, themselves and now Node A and Node C have entangled particles, or particles in common. This theory can be used as a method to get around obstructions, follow a circular path like communicating around the planet, or, once we get into space travel, a repeater to rebuild the signal, or particle, being passed along. A diagram of how a Bell Measurement causes a Bell State and creates a photon entanglement is illustrated in figure 2.

Figure 2



Now since photons move at the speed of light, one might think of quantum communications as an instantaneous communications method. Due to the fact that the sending node sends only one of the entangled pair, it takes time for the receiving node to get the reference particle and perform the Bell Measurement. Now this may seem like a lot of actions to perform, but compared to conventional wireless communication methods, this will be far faster with further range.

Universities, private firms and government agencies around the world have taken up the task of research and development for the emerging technology of quantum communications. The Department of Defense, Army Research Office, IBM, National Institute of Standards and Technology (NIST), University of Geneva, University of Oxford, University of Vienna, and the European Research Network are just a few of the groups that are collaborating to further progress quantum communications.

The European Research Network is a collaboration of the groups, Quantum Experiments and the Foundations of Physics, University of Innsbruck, The Oxford Quantum Computation and Cryptography Group, Group of Applied Physics (GAP), Institute for Scientific Interchange Foundation, and Max-Planck-Institut für Quantenoptik (MPQ). The European Research network's main areas of research are quantum communications, quantum cryptography, and quantum computing. Their objective is to: "Theoretically and experimentally, study linear and non-linear multiports as building blocks of quantum information. This will include the investigation of quantum phenomena to improve channel capacity and the transfer of quantum states (quantum teleportation)"**(**The Physics of Quantum Information European Research Network**).**

The University of Vienna and the Austrian Academy of Science have made important strides in the area quantum communications this year. In April of 2004, physicists carried out a successful teleportation of particles of light over a distance of 600m across the River Danube in Austria. Another test site is in United Kingdom where Quantum Communications was used to send information along a 10 Kilometer line under a street. These are very significant accomplishments, because unlike laboratory test, these tests were a success in "real world" conditions (Lionel).

Around the same time of the Austrian experiment, the Institute of Standards and Technology (NIST) had similar success in teleporting particles of light. The main difference between the two groups, according to the reports, was that the NIST team manipulated beryllium atoms with gold electrodes, and the Innsbruck researchers trapped calcium atoms at temperatures around 15 millionths of a degree above absolute zero (Lionel).

Previously quantum information had only been passed that told the quantum states of beams of light. Before that experimenters were successful only within a range of probability. The recent experiments have something more on the order of 78 percent accuracy (Lionel).

Future Trends in the area of quantum communications includes cryptography and quantum computing. Quantum-level communications and computers are potentially powerful tools in the homeland security arsenal. For example, quantum communication devices are highly secure communication systems, as they make eavesdropping on data communications impossible. Additionally, quantum computers will have the ability to store and process a much larger amount of information than the most powerful computers presently in existence(Lum, Martin, and Pitchford).

Quantum communications would exponentially advance deep space communication. Data is currently represented in binary as ‘off’s and ‘on’s, but with energy it would be presented as distinct polarizations of photons. Therefore, by sending a photon with a positive 45-degree spin, people could effectively send a binary ‘on’. Teleportation of energy would thus mean instantaneous communication between two points, since the time wasted transferring the information is removed. Communicating with satellites and Martian rovers would be real time instead of delayed and live video broadcast from our celestial neighbors would be possible.

Quantum cryptology is a promising technology for data security. Since there are four states for sending data with teleportation, a hacker needs to spend a good deal of time deciphering the code used to produce the encryption (Harrison). Since the receiver of the data chooses a new code each time, a hacker cannot reapply a previous decryption to a message and expect it to work, thus the hacker would encounter countless problems trying to decrypt the data and never be able to receive the information. Another beneficial property of teleportation is that changes are made to the data if someone tries to intercept and read the information. The sender could detect that someone that is not authorized is receiving the information because the quanta has changed (Harrison). Quantum cryptography will allow the most secure communication lines for bank-to-ATM transactions, financial information protection over the internet, and military and government communications including the use for ship-to-ship, ground-to-satellite, and satellite-to-satellite communication (Nazarian).

There are currently no regulatory issues surrounding Quantum Communications because Quantum Communications is still in the experimental stage. Currently, the only steps being taken are experiments with the technology. There are several colleges currently experimenting with Quantum Communication but there is no live testing being done, at this point in time, in professional fields. This technology will require the use of a new type of communication equipment. The Federal Communication Commission (FCC) and American National Standards Institute (ANSI) will have to be notified and the equipment must have a FCC and ANSI approval and stickers in order for the public to use the equipment.

Before any type of experiments by private companies can take place the FCC will have to make a ruling to determine if Quantum Communications will fall under Experimental Radio Services. If the FCC determines this to be the case then paperwork must be filled out before any private companies will be allowed to experiment with Quantum Communications. If the FCC deems this to be the case, then an experimental license, FCC form 442, will have to be filled out and sent to the FCC. The experimental license is good for a two year period and can be extended to a five year period if requested. On the other hand if the FCC rules Quantum Communications does not fall under Experimental Radio Services then no paper work will need to be filled and private companies can develop the technology without the FCC paperwork. The FCC will have paperwork and rules to follow once the technology is viable and ready to be used on the open market.

Once the technology for Quantum Communication is working and it is a viable resource a few things must happen before any company or government can use the technology. First there will have to be paperwork filled with the FCC to get the approval of the FCC. To get the FCC approval the following steps needs to be taken. The first filling is the Remittance Advice the FCC form 159. Once the form is filled out and submitted to the FCC along with the appropriate fees. The FCC will assign an Applicant/Grantee Code. Once you have received the Applicant/Grantee Code you will need to have the device tested at a FCC approved test laboratory. Once you receive the Applicant/Grantee code from the FCC and the test report from the test laboratory, you can then forward it to FCC and completed the Application for Equipment Authorization this is done online through the FCC form 731 and this form is located at https://gullfoss2.fcc.gov/prod/oet/cf/eas/index.cfm. This is only the first of many steps needed to get the FCC approval for the equipment used in Quantum Communications. Because of the type of technology involved the FCC may require public hearings on the technology and public input may become political in nature because of the ramifications of the technology. The other item required by the FCC is getting a FCC certification. This requires submittal of an application that includes a complete technical description of the product and a measurement report showing compliance with the FCC technical standards also the FCC is requesting the Declaration of Conformity (DoC). These steps are also the procedures and labeling requirements for personal computers and personal computer peripherals.

In order to get ANSI approval the following steps need to be followed. The Preliminary Application Process must be done first and then the application process must be followed. Below are the steps needed to be followed for each application.

1. Preliminary Application Process

a. ANSI receives a request for an Application Package.
b. ANSI mails application package to prospective applicant.
c. ANSI receives a Preliminary Letter of Application.
d. ANSI mails a Confirmation Letter of receipt of Preliminary Letter of Application within 5 working days.
e. ANSI evaluates Preliminary Letter of Application (ANSI will directly contact prospective applicant if there is a problem with the Preliminary Letter of Application).
f. ANSI issues Eligibility Report within 30 days of receipt

2. Application Process
    a. ANSI receives application, supporting documentation and application fee.
    b. ANSI mails a confirmation letter of receipt of application, supporting documentation, and application fee.
    c. ANSI Accreditation Committee Chair is notified of receipt of application.
    d. Accreditation Committee is notified of receipt of application.
    e. Request volunteers from the Accreditation Committee to serve on the applicant's Evaluation Task Group.
    f. Announce the receipt of an application for accreditation in ANSI's Standards Action, requesting comments within 30 days.
    g. Send letter to the applicant requesting approval of Committee members who have volunteered to serve on the applicant's Evaluation Task Group (2 members required).

h. ANSI receives approval from applicant of 2 members for the Evaluation Task Group.
i. If appropriate, the applicant responds to comments received from Standards Action announcement.
j. ANSI reviews application and supporting documentation (ANSI will directly contact applicant if there is a problem with the application)
k. ANSI develops estimated initial assessment expenses.
l. ANSI issues a letter of acceptance of the application and supporting documentation along with an invoice for the first 1/3rd payment of the estimated initial assessment expenses.
m. ANSI provides the documentation received from the accepted application to A2LA with request for assessor and technical expert to participate on the assessment team.
n. ANSI identifies the qualifications of the assessor(s) comprising the assessment team.
o. An assessment plan is developed and issued to the applicant for approval of plan and assessment team.
p. ANSI to conduct an assessment of the applicant's headquarters, other sites, etc.
q. ANSI to conduct a witness assessment of the applicant's inspection of a licensee facility. Applicant to implement Corrective Action of Non Conformities cited.

r. ANSI prepares and issues an assessment report to applicant & Evaluation Task Group. If ANSI staff and Evaluation Task Group recommendation is to accredit applicant, ANSI issues ballot to the ANSI Accreditation Committee (Ballot Period is 3 weeks).

s. Negative ballots thus negative comments (if any) are forwarded to the Committee for review and resolution.

t. If applicant is approved for accreditation program, two contracts are developed and issued to the newly accredited organization for signature.

u. ANSI VP, Conformity Assessment signs two contracts which have been signed by the newly accredited organization.

v. ANSI mails one copy of the originally signed contract to the newly accredited organization.

w. ANSI prepares and issues Accreditation Certificate(s).

x. ANSI announces newly accredited organization in ANSI's Standards Action.

y. ANSI adds newly accredited organization to ANSI Directory of Accredited Programs.

The global implication of Quantum Communications will be quite large. At some point in the future all bank transaction and highly classified information sent from one place to another will be using Quantum Communication because of the nature of the Quantum Mechanics. Once the technology has matured and people realize the advantages of knowing if someone has looked at the date of the transmission, this type of technology will become widely used. Until the technology is ironed out and the cost drops to a point where the average person can acquire the hardware and software needed to accomplish Quantum Communications, this type of technology will only be used in banking transaction and government movement of classified information over the Internet or along a single wire. The other part of Quantum Communications will be the ability to send objects from one location to another location. For those people who follow Science Fiction this will be teleportation and this alone, if it becomes a reality, will change the face of the world as we know it today. Teleportation will change the world on an order compared with the way the printing press changed the world.

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