Analyzing the Quantum Based Satellite Communications

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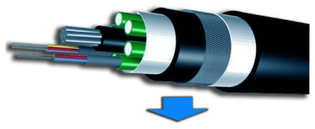
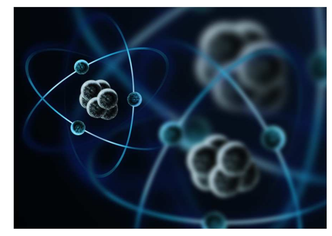
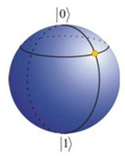
Quantum Communicatons

• Although quantum computers are going to be the tools of the far future, there are already algorithms existing to solve problems which are very difficult to cope with by traditional computers: quantum parallelism, search in an unsorted database, quantum key distribution etc.
• For an improved satellite communication system we need better hardware, better software and better solution for the transmission - irrespectively of what better means.





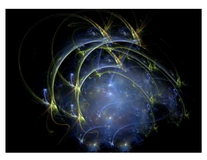


quantum based satelite communication

The free-space quantum communication can be extended to ground-to-satellite or satellite-satellite quantum communication, which could be an ideal application for global quantum cryptography.

Research problem

• For engineers, the properties of the quantum channels are very interesting. How will the performance of quantum algorithms be affected if the physical layer is changed from optical fiber to the free-space, and the length of the channel increases dramatically?
• For the quantum satellite communications, a quantum channel with a length of 300-33,000 km is needed. What are the limits of quantum algorithms with our current techniques?
• Can we use redundancy-free coding technique?



we need **precise models** of quantum channels

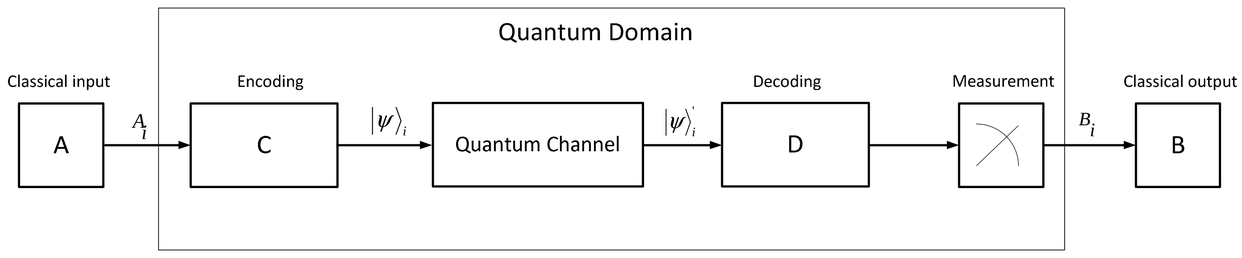


Figure 1. Transmission of classical information through the satellite quantum channel.

We encode the classical information into a quantum bit, then we send the quantum bit over the quantum channel. At the end we have to decode and measure it to get back a classical information.

Model

• Our research group has created a model that describes the behaviour of weak laser pulses to simulate the communication process over a satellite quantum channel.
• The effects of aerosols and the optical turbulence of the atmosphere on quantum communication, and the finite size of the detectors and the beam spreading induced by diffraction were taken into account as well.

BB84 in satellite communications

• The most famous flexible asymmetrical quantum protocol is the BB84 protocol
• How will the system perform in different climates, weather and season conditions?

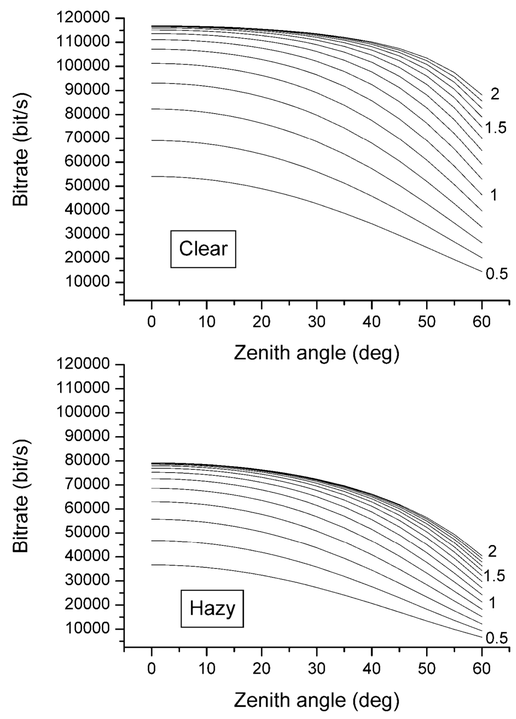


Figure 2. Bitrates of BB84 secure key generation rate in space-Earth communication at various seasons, latitudes and weather conditions. Labels over the graphs indicate Bob's detector diameter in meters. The laser pulses are generated at a 1 MHz rate.

Superdense coding in satellite communications

• In a best case scenario, Alice and Bob already share an entangled qubit pair, and thus every qubit sent by Alice that arrives at Bob's detector carries information worth of two classical bits.
•The **feasibility** of the superdense coding in Earth-satellite communication raises many questions. What diameter is needed for Bob's detector at minimum, and what is the optimal size? What will be the transmitance of the system in different conditions?

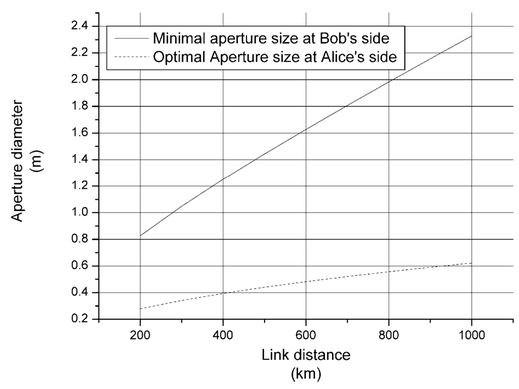


Figure 3. Superdense coding, optimal aperture size at Alice's side (at which the beam spreading is lowest) as the function of the link distance has been plotted by continuous line. Dashed line represents minimal aperture diameter at Bob's side for the protocol to be worthwhile.

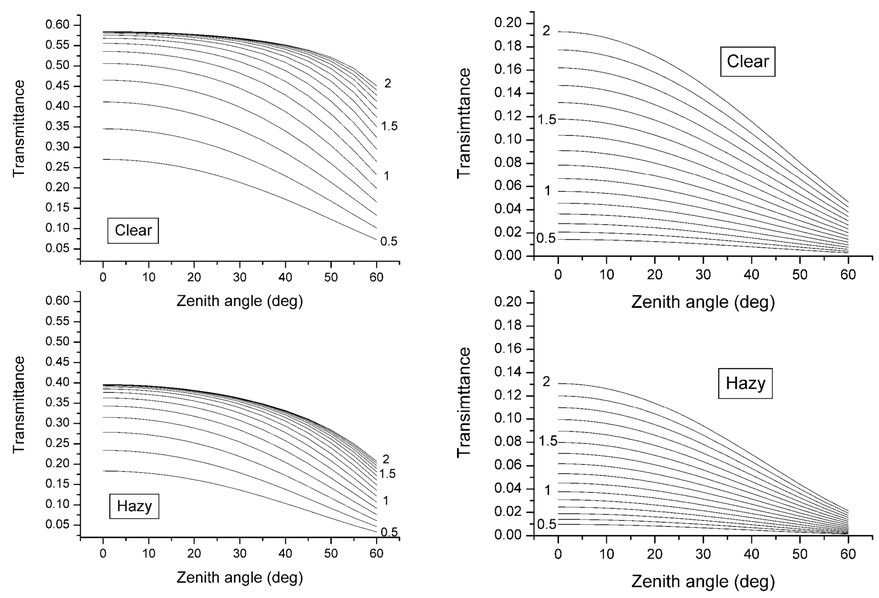


Figure 4. Superdense coding, Transmittances in space-Earth communication (*downlink left, uplink right*) at various seasons, latitudes and weather conditions. Labels over the graphs indicate Bob's detector diameter in meters. Alice's aperture size is fixed as 0.2, the satellite is orbiting at 300 km.

Redundancy free coding

• The goal is to construct a communication channel, which is an error-free channel for the classical communication. However, it does not mean that there is a need for an error-free quantum channel as well.
• The aim is that the quantum error appearing in the quantum channel does not have any effect on the original classical information which was encoded into the quantum bit.

using **eigenvectors and eigenvalues** of the channel

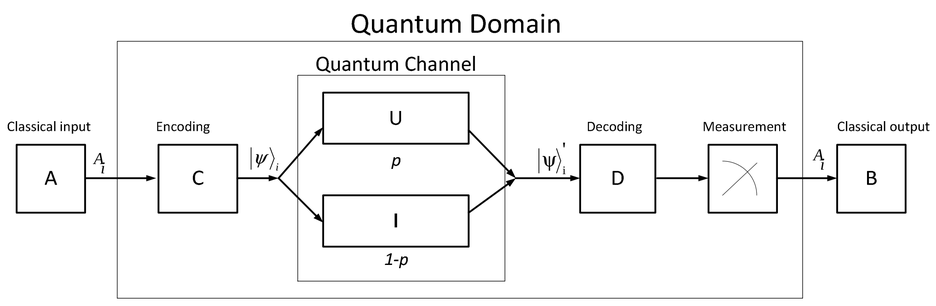


Figure 4.

The channel model. It transforms a unitary transformation with probability *p* , and an identity transformation with probability *1-p*. This will not be a mutually unambiguous transformation in quantum domain, however, if the initial classical bits are coded into qubits using a special encoding transformation denoted by *C*, one can construct such a transformation denoted by *D* which produces the same classical values after the measurement.

Results and future work

• Calculations based on the optical losses let us conclude that deep space links and uplinks cannot be realized with superdense coding.
• We also examined the BB84 protocol's performance in downlinks. Our results show that satellites at low earth orbit can produce secure keys even at large zenith angles and hazy weather.
• By using these redundancy-free techniques, the effective capacity of the satellite link could be increased.

The poster is based on work of our quantum research group at BME Dept. of Telecommunications

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