# Statistical Analysis of the SECOQC QKD Network in Vienna

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## Abstract

The aim of our work is to carefully evaluate external influences like temperature, humidity, sunshine duration and global radiation on the quality of Quantum Key Distribution (QKD). It will be explained how qubit error rate (QBER) is correlated to these external influences. The correlations between the different influences will be analysed using statistical methods, in special the Gaussian generalized linear model. The base data for our work was taken from various experiments during the SECOQC QKD network installation in Vienna.

## Introduction

Quantum Cryptography is an interdisciplinary field of quantum mechanics and computer science which has been of major interest to the scientific community in the last 25 years. In quantum cryptography, quantum mechanics is used to guarantee unconditional secure communication. A very important part of quantum cryptography is Quantum Key Distribution (QKD), which has already been realized in various experiments. The aim of this paper is to find out the quantity of external influences like temperature, humidity, sunshine duration and global radiation on the quality of QKD. In the course of the SECOQC project [1] measurements in the prototype network in Vienna have been performed. Within these measurements we focused on the variation of the key generation rate due to environmental influences. The correlation will be analysed using statistical methods in special generalized linear models.

The presented method will be extended to evaluate more measurements generated by the SECOQC network and subsequently published elsewhere. The results have also been submitted to the Third International Conference on Quantum, Nano and Micro Technologies [2].

## Polarization Measurements

QKD is based on correlations retrieved by measurements on single photons. Therefore it is essential to guarantee acceptable polarization stability for the quantum channel connecting the sender and the receiver. In contrast to classical communication, effects like depolarization of optical fibers could have negative influences. Thereby the degree of polarization (DOP) of a highly polarized laser diode was measured after transmission. This study should give information about a possible impact on environmental data. One main influence factor is the temperature. Isolated measurements in the laboratory showed that the temperature had a negative effect on optical fibers on a spool, but the amount of the degree of polarization never reached an unacceptable value (DOP<98%). An analysis of correlation between the DOP and the temperature had the result of weak correlation values (Bravais-Pearson Analysis).

The same measurements were made with realistic installed cables as device under test. Different cables with different courses were used to analyze different effects at different times (temperature, humidity, traffic vibration). An analysis of correlation between the DOP and the temperature had the result of a weak to an insignificant correlation value. The same was true for the analysis of the humidity and the DOP. The reason for that is that the cables are well installed in the earth so that external temperature changes have not the effect like in the laboratory measurements. Even the largest recorded temperature change of 15° within some hours had only a very small relevance to the DOP at installed fiber optic cables. The humidity had less influence than the temperature and is absolutely irrelevant for the degree of polarization. An exact influence factor of the traffic vibrations could not be defined yet but if there is an effect it is also not a strong interference factor. In general all tested fiber optic courses would fulfill the requirements to use QKD concerning the degree of polarization.

## Measurements on a QKD-link

For the **experiment in the laboratory**, Alice and Bob were connected with a nonzero-dispersion-shifted-fiber with a length of 25 km and an attenuation of 0.2 dB/km. The measurements were performed over 12 hours. To find out pairwise correlation it is possible to plot QBER and final keyrate as shown in Fig. 1. A high correlation between the two variables is indicated by a straight line or an ellipse in the plot. Furthermore, there is a differentiation between a positive correlation and a negative correlation which depends on the orientation. As expected, the scatterplot QBER and key rate is negatively correlated, with a correlation value of -0.703.

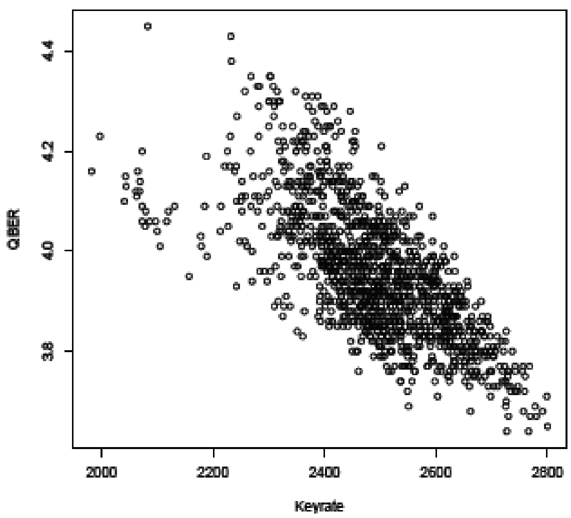


*Figure 1: Correlation between QBER and final key rate*

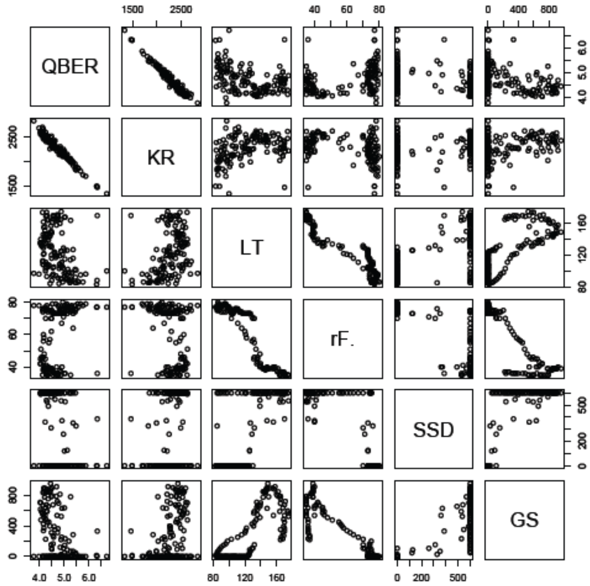


*Figure 2: Scatterplot matrix for the dataset*

Note that the measurements took place without external influences like temperature or humidity. The main focus in this dataset is on the permanence in QBER throughout the measurement, which ranges between 3.64% and 4.45%.

The **measurements in the fiber ring network** in Vienna started on April, 23rd 2008 and the QKD systems were positioned in the SIEMENS Austria location in ERD. The route ERD-GUD-ERD was used where the fiber had a length of 12 kilometers with an attenuation of 0.2 dB/km. The measurements in this real-life environment took 24 hours.

In Fig. 2 the scatterplot of this dataset is shown. Here QBER denotes the qubit error ratio, KR denotes keyrate, LT denotes air temperature, rF denotes relative humidity in %, SSD denotes sunshine duration and GS denotes global radiation. In Fig. 2 it can be seen that QBER and the key rate are highly correlated. The detailed information about the variables is given in the correlation matrix in Table 1. The fact that QBER and temperature are correlated to a lesser degree is remarkable. This means that the temperature has small influence on QBER which will be described in detail in the following.

**Table 1: Correlation matrix of Fig. 2**

| | QBER | KR | LT |
|---|---|---|---|
| QBER | 1.0000000 | -0.9831817 | -0.3820906 |
| KR | -0.9831817 | 1.0000000 | 0.3555813 |
| LT | -0.3820906 | 0.3555813 | 1.0000000 |
| rF. | 0.3989938 | -0.3430902 | -0.9320877 |
| SSD | -0.3781499 | 0.3075375 | 0.7059361 |
| GS | -0.4432206 | 0.3913160 | 0.7733735 |

| | rF. | SSD | GS |
|---|---|---|---|
| QBER | 0.3989938 | -0.3781499 | -0.4432206 |
| KR | -0.3430902 | 0.3075375 | 0.3913160 |
| LT | -0.9320877 | 0.7059361 | 0.7733735 |
| rF. | 1.0000000 | -0.8330456 | -0.9059995 |
| SSD | -0.8330456 | 1.0000000 | 0.8298786 |
| GS | -0.9059995 | 0.8298786 | 1.0000000 |

## Discussion of the results and conclusions

Both, the laboratory data and the real-life data are processed using statistical methods in special the Gaussian generalized linear model (Gaussian GLM).

QBER of the laboratory dataset has a mean of 3.9% and the rate fluctuates between 3.6% and 4.5%. In contrast the real-life data has a mean of 4.7% and the fluctuation is between 3.7% and 6.7%. The correlation matrix in Table 1 shows that QBER is correlated with air temperature, humidity, sunshine duration and global radiation to a lesser degree.

The resulting conclusion drawn from the statistical analysis is only a small influence of air temperature, humidity, sunshine duration and global radiation on QBER and final key rate, which can be well described by means of a generalized linear model.


### Acknowledgement

Alexander Treiber and Hannes Hübel from the University of Vienna provided us with the corresponding data of QKD-link and Roland Potzmann from the Central Institute for Meteorology and Geodynamics (ZAMG) provided us with the climate data.


## References


1. A. Poppe, M. Peev, and O. Maurhart: Outline of the SECOQC Quantum-Key-Distribution Network in Vienna International Journal of Quantum Information, Vol. 6, No. 2 (2008).
2. K. Lessiak, C. Kollmitzer, S. Schauer, J. Pilz, S. Rass. Statistical Analysis of QKD Networks in Real-life Environments, submitted to the Third International Conference on Quantum, Nano and Micro Technologies to be held in Mexico 2009.