Summary Report on
Entanglement based satellite QKD Simulation Result

This time I have worked out for the satellite pass that mimics similar to Micius satellite of which data is published in the literature.
The later part of this report contains the analysis of different satellite passes.

INPUT PARAMETERS

S.no.	Parameter	Simulation	Experiment	
1.	Runtime	285 s (>13° elevation angle for both ground stations)	285 s (>13° elevation angle for both ground stations)	
2.	Spectral width of signal/idler photon (Standard deviation)	1000 ps	NA	
3.	Photon-pair generation rate	$5.9 * 10^6$ /s	$5.9 * 10^6$ /s	
4.	Channel link efficiency	(on next page)	NA	
5.	Atmospheric timing jitter	0	NA	
6.	Imperfection in polarization	π/16 (standard deviation)	NA	
7.	Background photons	$12 * 10^3$ cts (at each ground station)	NA	Need to fine-tune this number as per the experiment.
8.	Beam splitter	0	~10%	
9.	Polarization Beam splitter	0	NA	
10.	Detector Efficiency	{53.31, 53.64, 53.16, 53.16, 53.78, 53, 53.16, 53.16}	{53.31, 53.64, 53.16, 53.16, 53.78, 53, 53.16, 53.16}	
11.	Detector dark count	{55, 207, 60, 55, 32, 55, 64, 26}	{55, 207, 60, 55, 32, 55, 64, 26}	
12.	Detector deadtime	20 ns	NA	
13.	Detector timing jitter	600 ps	NA	
14.	Coincidence window size	2.5 ns	2.5 ns	

NA: Data not available

OUTPUT RESULTS

S. no.	Parameter	Simulation	Experiment	Comment
1.	Total time	3135 s	3100 s	In simulation 11 datasets are collected
2.	Sifted key bits	2934	3100	
3.	Sifted key rate	0.936 bits/s	1 bit/s	
4.	Error bits	203	140	
5.	QBER	6.92%	4.51%	

The cause of the difference in the Simulation and Experimental result is

1. The theoretical values of loss (in dB) deviate from the experimental data. (cause error in Shifted Key rate)
2. The value of the background thermal photons rate is not available in the experimental data. (Majority of the QBER is caused due to the background thermal photons rate)

The simulation incorporates a lot of parameters that have a relatively wide range of effects (on QBER and Shifted key rate) mentioned in TABLE 1 that have the ability to fine-tune the model.

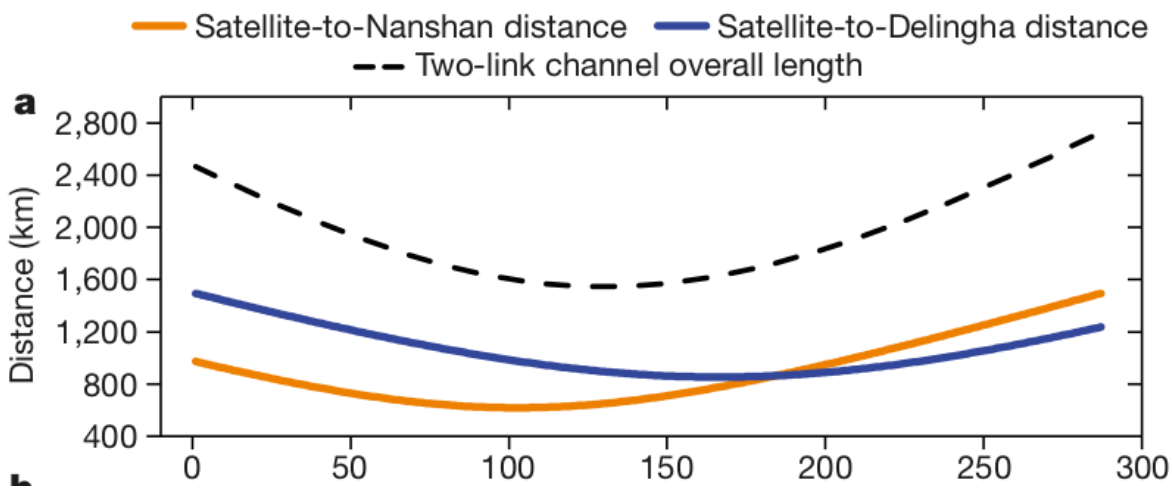
The link efficiency data or the losses calculated (using *EXTRANEOUS ELEVATION DEPENDENT (EED) LOSSES(Finalversion).nb*) deviate from the experimental data causing a difference in the shifted key rate.

I have not included the detector efficiency in the calculation of the loss file in order to fit the Attenuation(dB) data of the experiment better.

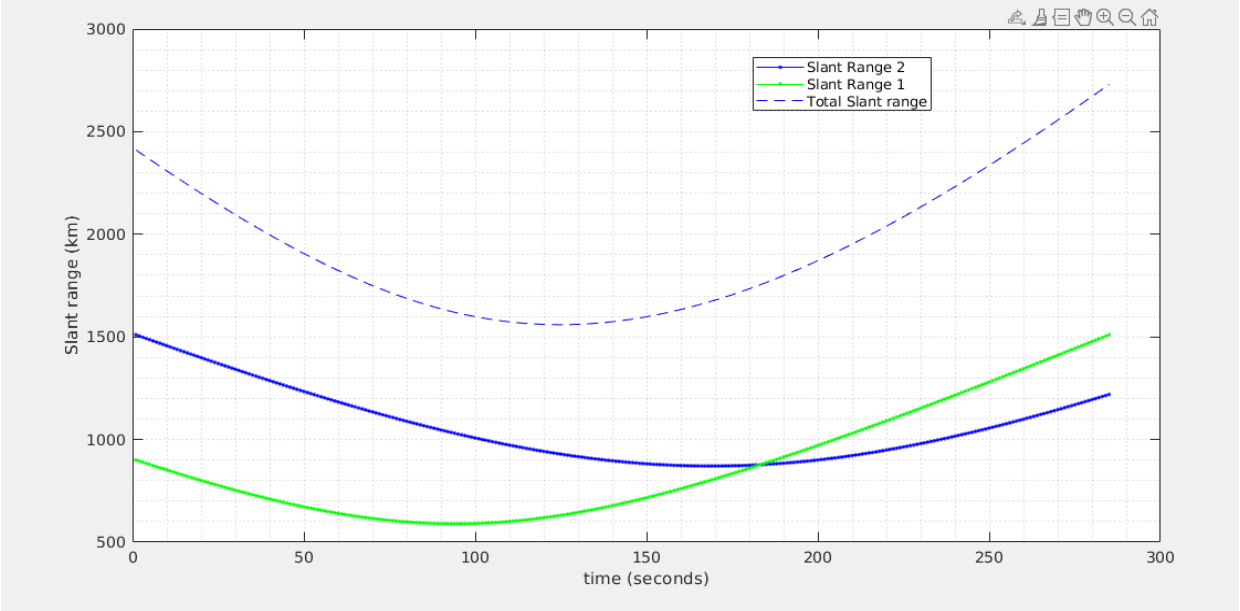
Instead in the simulation we separately process each detector as different with different parameters(efficiency, dark count, deadtime, timing jitter).

The main cause of the QBER is background thermal photons and then is the dark counts of detectors.

SLANT RANGE (EXPERIMENT vs SIMULATION)



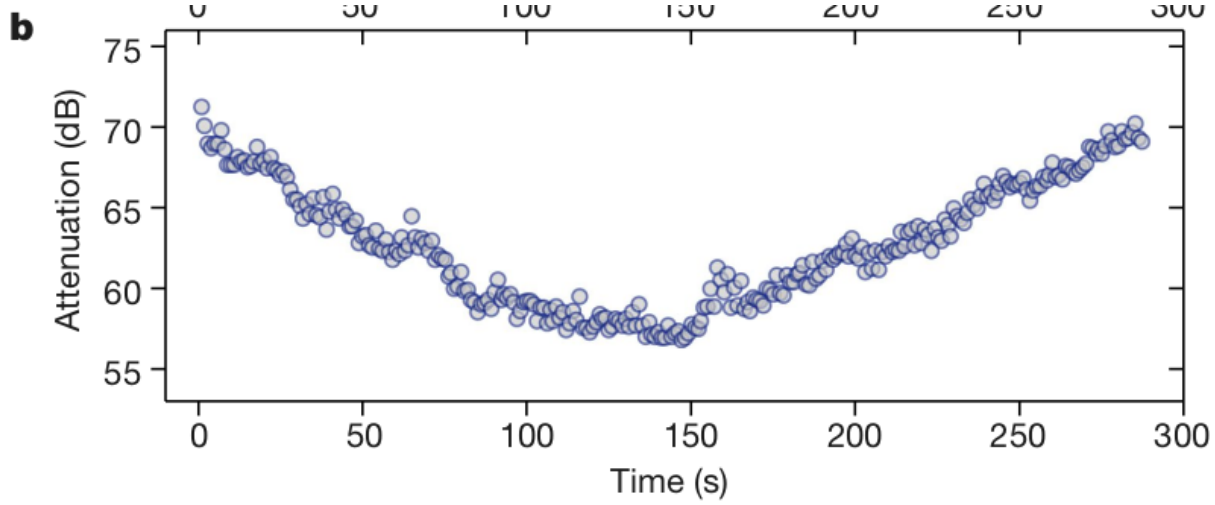
Experiment
(Nature, Entanglement-based secure quantum cryptography over 1,120 kilometres)



Simulation

LOSS (EXPERIMENT vs SIMULATION)

(Loss in simulation deviates from the experimental data)



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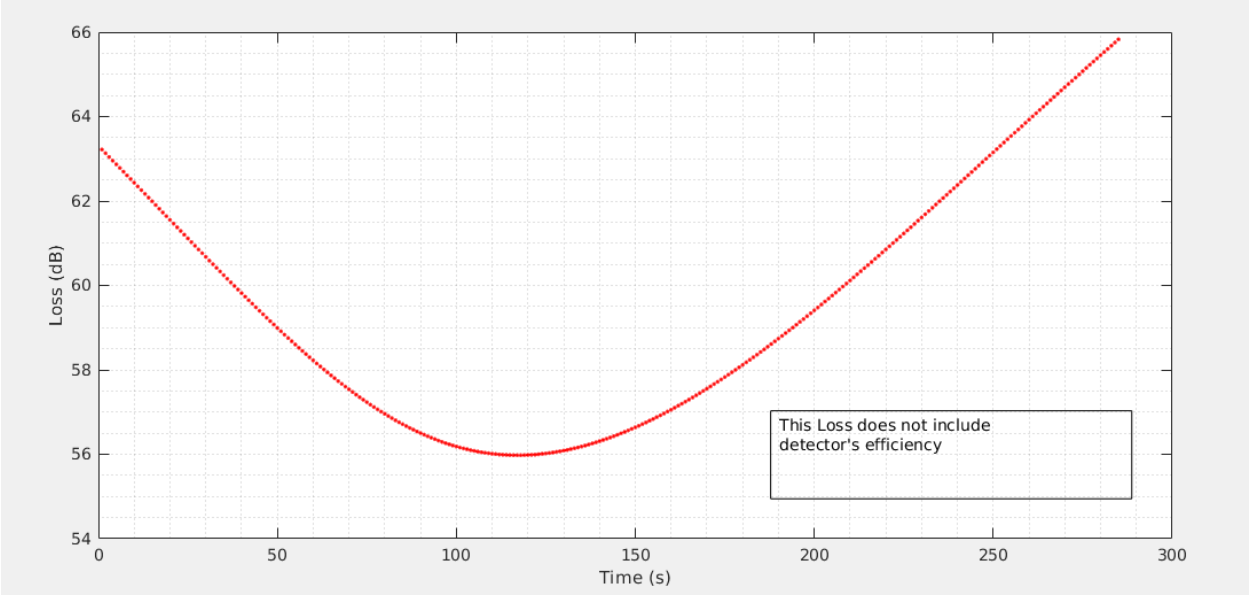
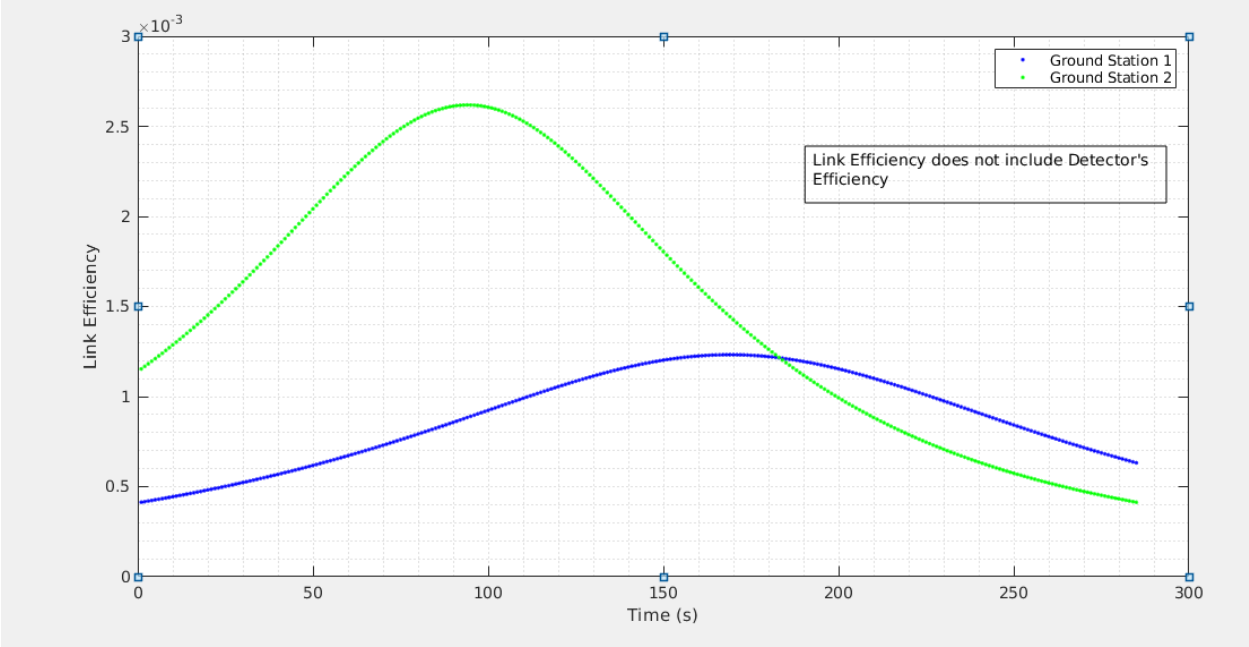
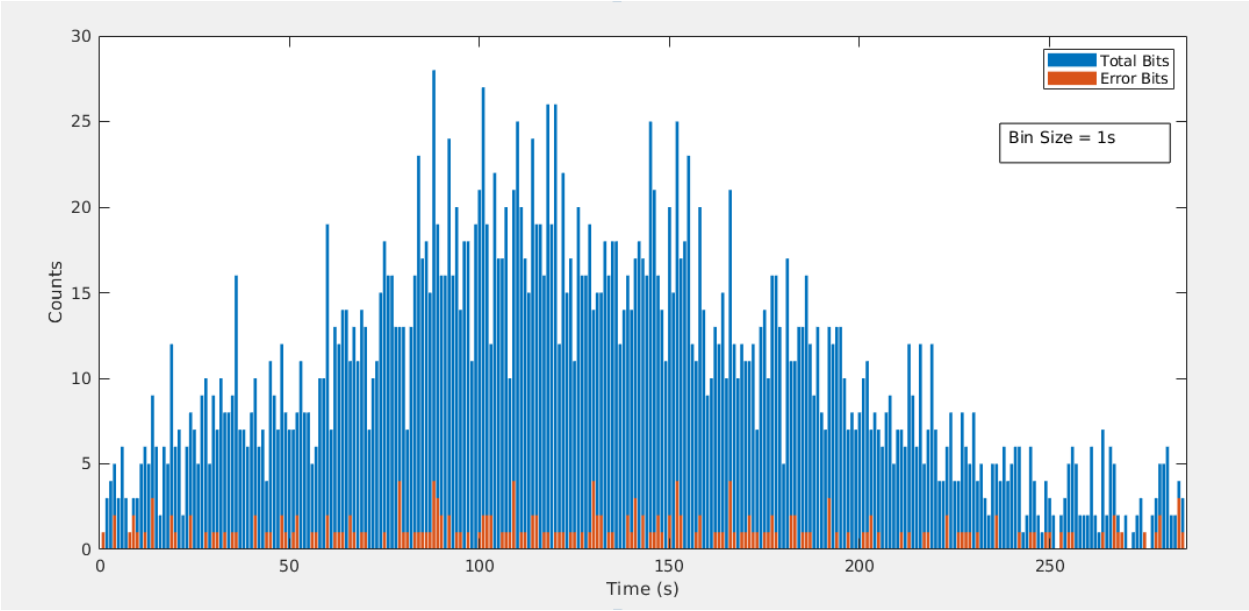


Simulation

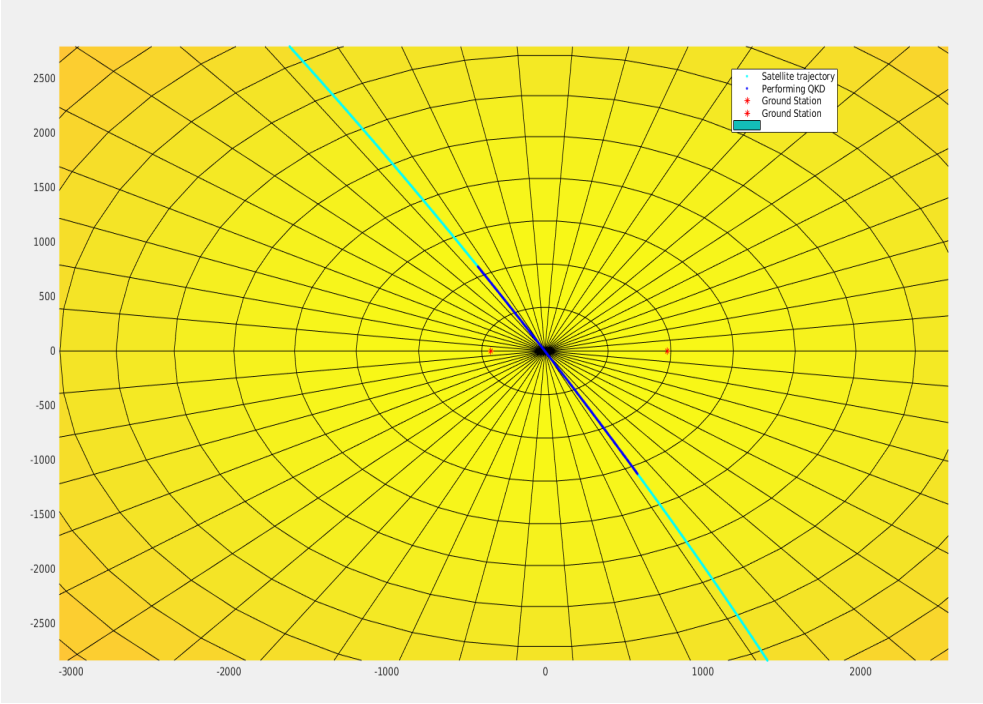
LINK EFFICIENCIES (Simulation)

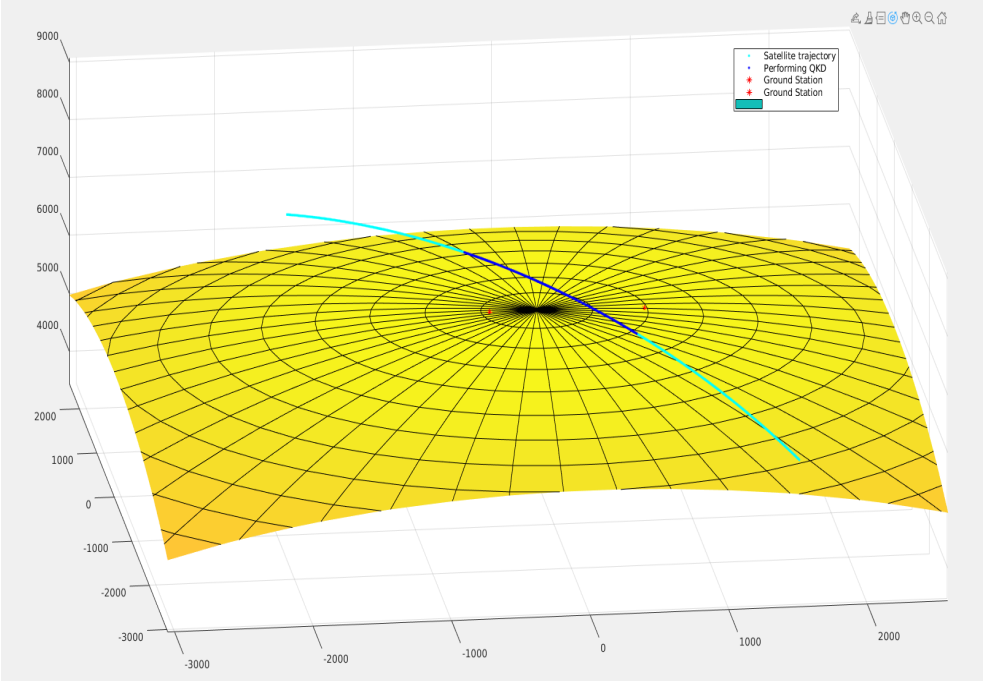


SIGNAL bits and ERROR bits obtained as function of time (cumulative of 11 datasets)

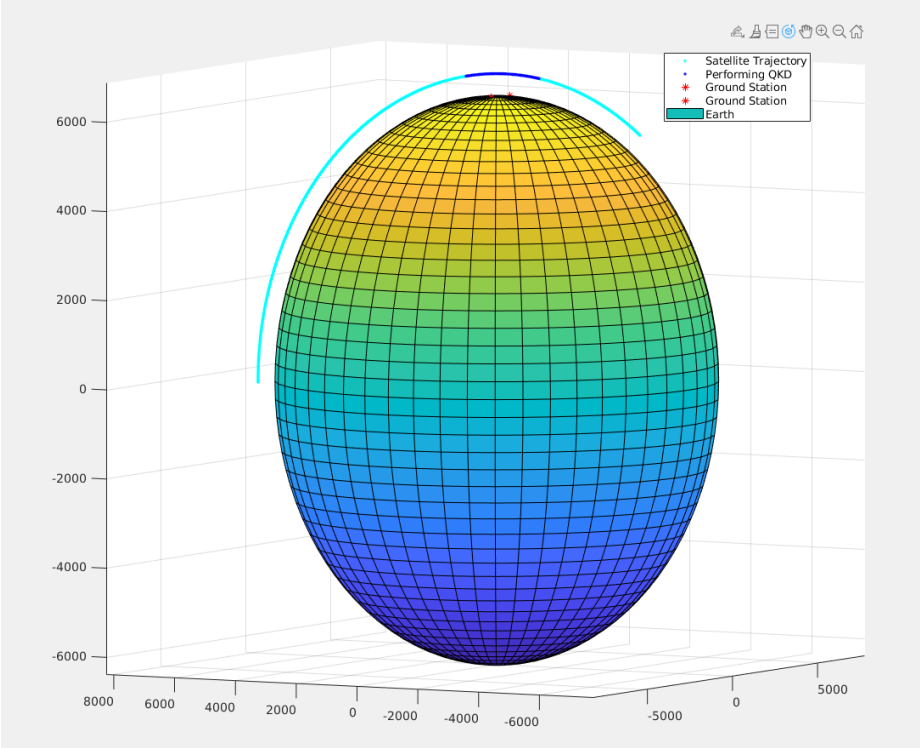


Satellite Trajectory (Top view of North Pole)





Satellite Trajectory (Side View)



ANALYSIS FOR DIFFERENT SATELLITE PASSES

Here are the 5 configurations for which data is presented below:

Configuration	No. of satellite passes	Time available per Pass for QKD (s)	Total Sifted Signal Bits	Total Error Bits	Average Sifted Key rate	QBER
S1	10	232	3374	166	1.526 bits/s	4.69%
S2	10	239	3132	185	1.388 bits/s	5.58%
S3	10	262	2858	172	1.156 bits/s	5.68%
S4	10	301	2503	187	0.894 bits/s	6.95%
S5	10	355	2608	192	0.789 bits/s	6.86%

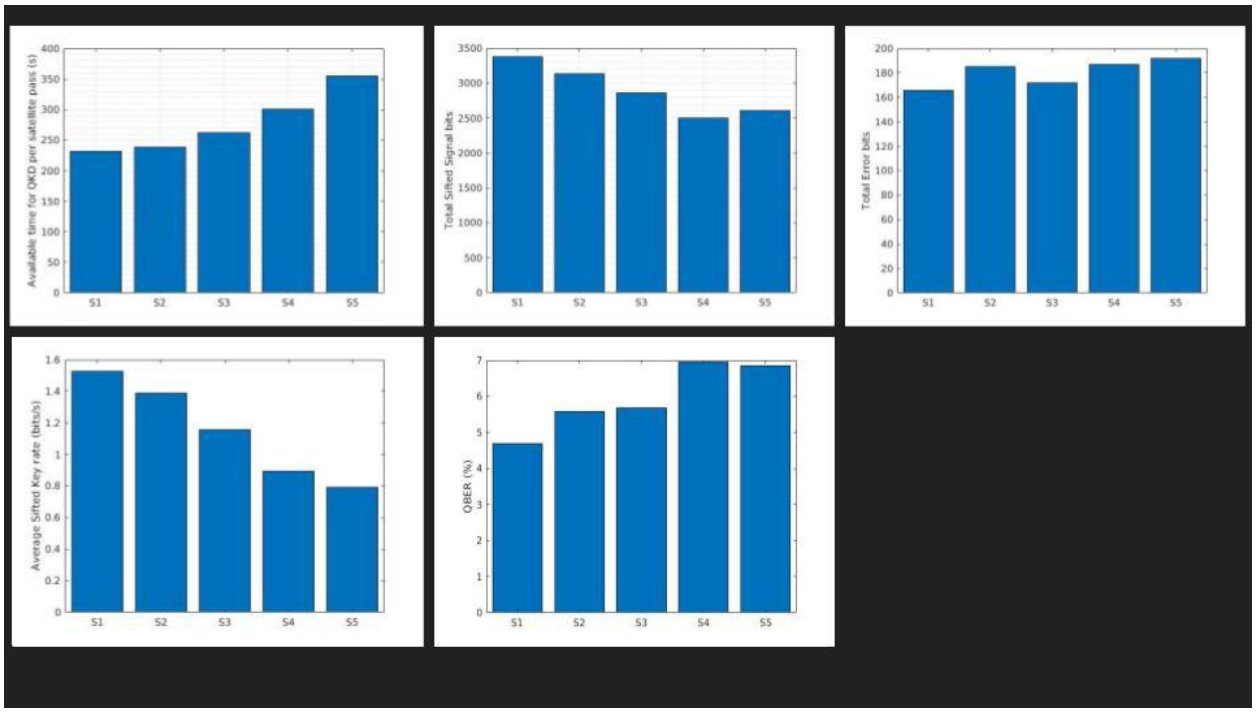


Figure: 1. Time available for QKD per satellite pass (Elevation angle > 13° for both ground stations)

2. *Total Sifted Signal bits obtained*
3. *Total Error bits obtained*
4. *Average Sifted Key Rate (bits/s)*
5. *QBER*

(Configuration S1 to S5 are from left to right from the left top corner in every graph)

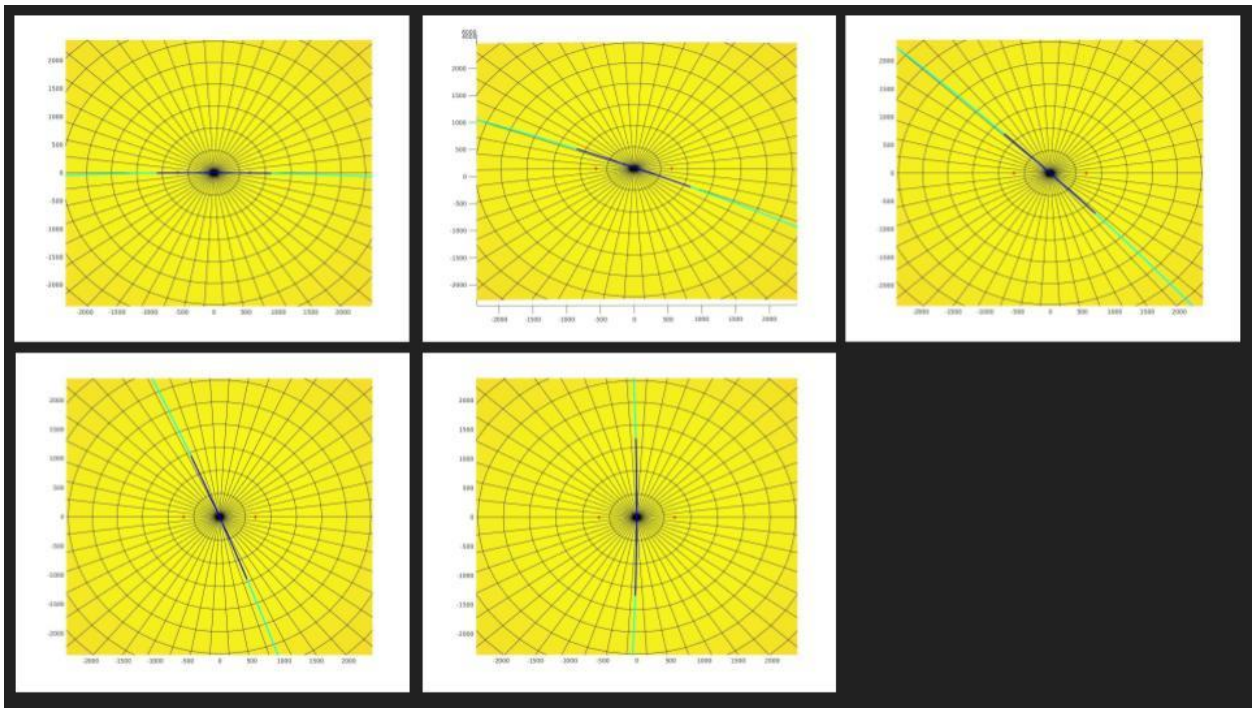


Figure: Trajectories of different satellite passes (green), elevation angle > 13° for both ground stations (blue) & ground stations (red)

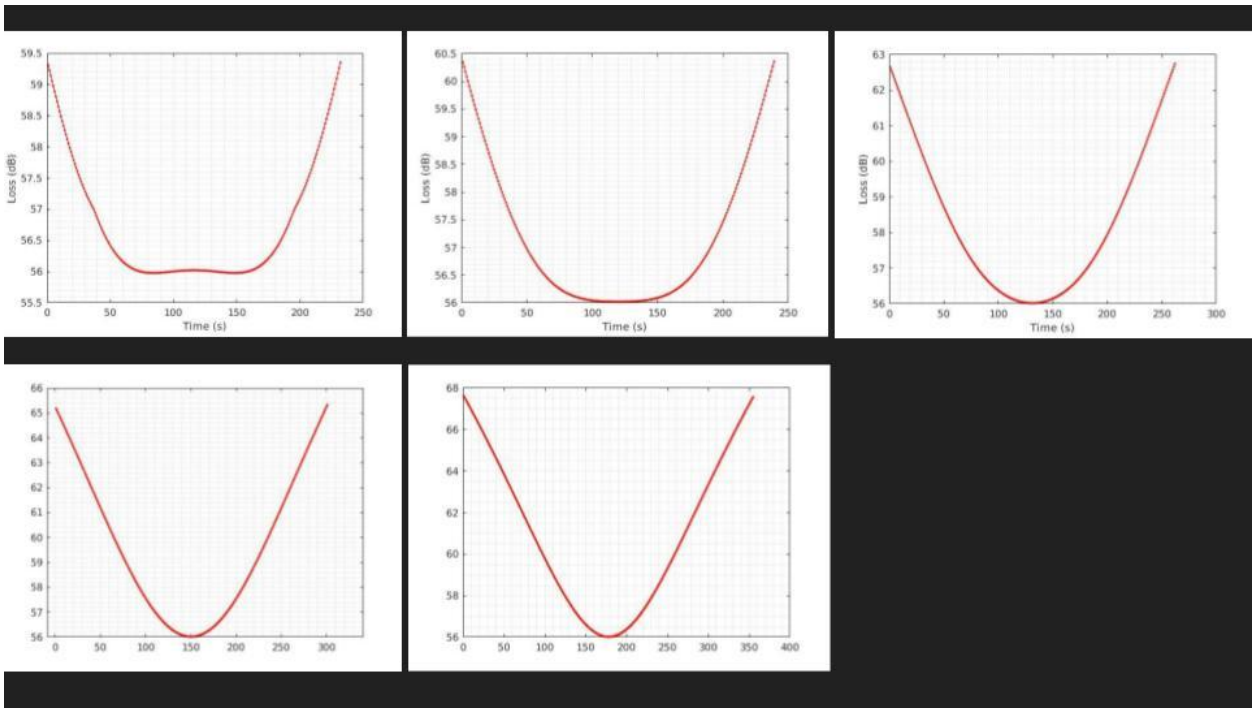


Figure: Total Loss (in dB) profile for different satellite trajectories

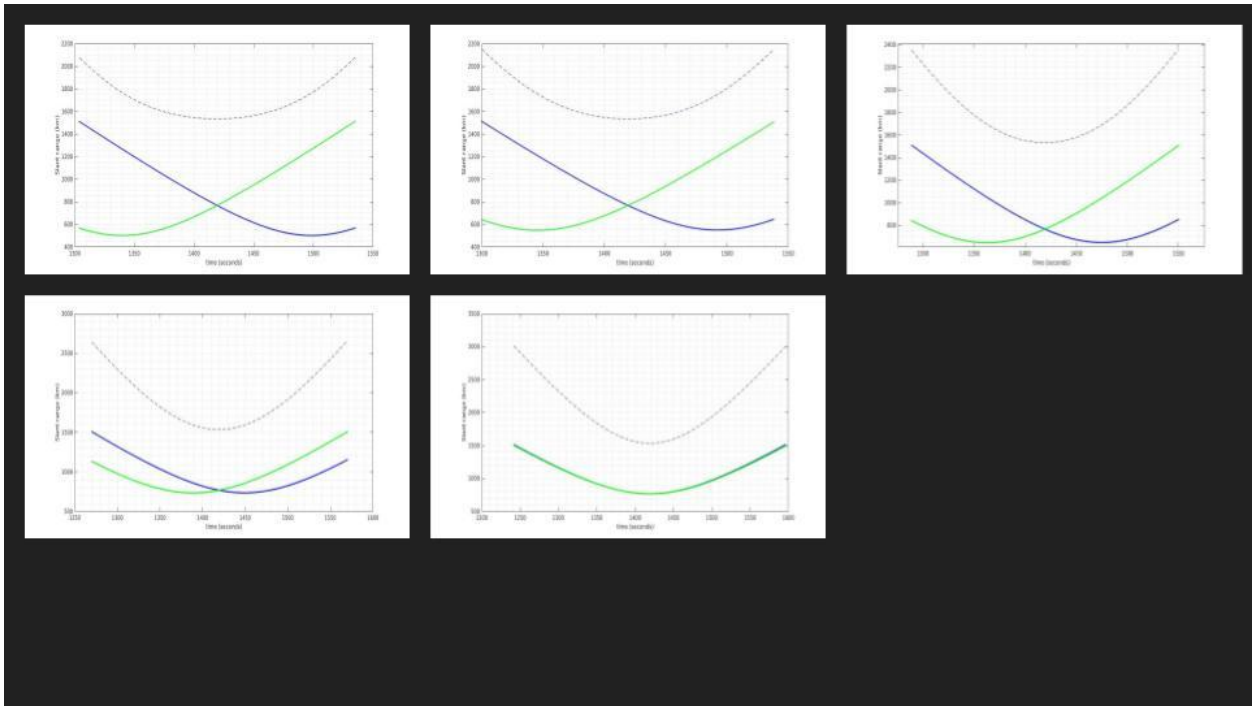


Figure: Profile of Slant Range from Ground Station 1 (Green), from Ground Station 2 (Blue) & Total Slant Range (Broken line)

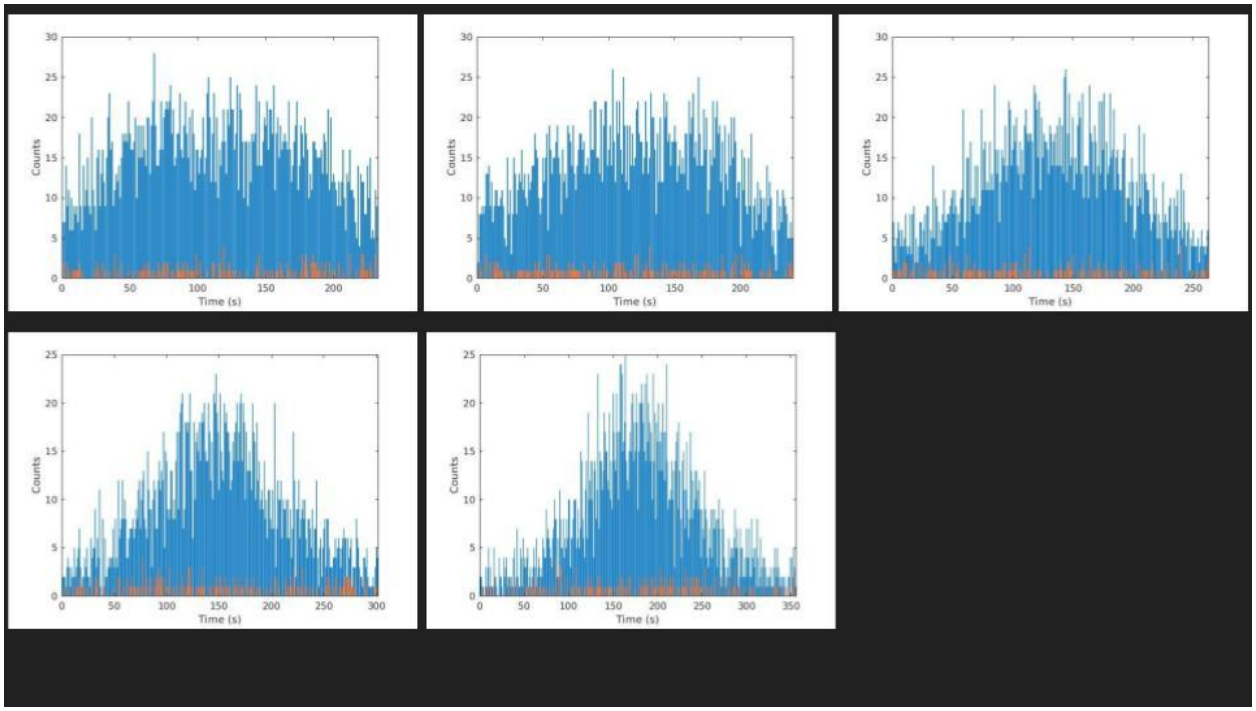


Figure: Sifted Key bits [Signal + Error] in BLUE bars and Error bits in RED bars as a function of time. {1 bar = 1 second}