Spectrum Monitoring – A Novel Approach

Gaurav Duggal
Shubhankar R Butta
Shubham Khanna
Kaustubh Singh

Spectrum Monitoring- Motivation

-Spectrum is expensive, monitoring its usage can help optimise its usage.

-In cell phone, channels are allocated to users on a real time basis depending on when a call is placed. So information about channel vacancy is required.

-Currently Wideband receivers are used to monitor spectrum. These wideband receivers are very expensive. We need a low cost alternative

Data Acquisition

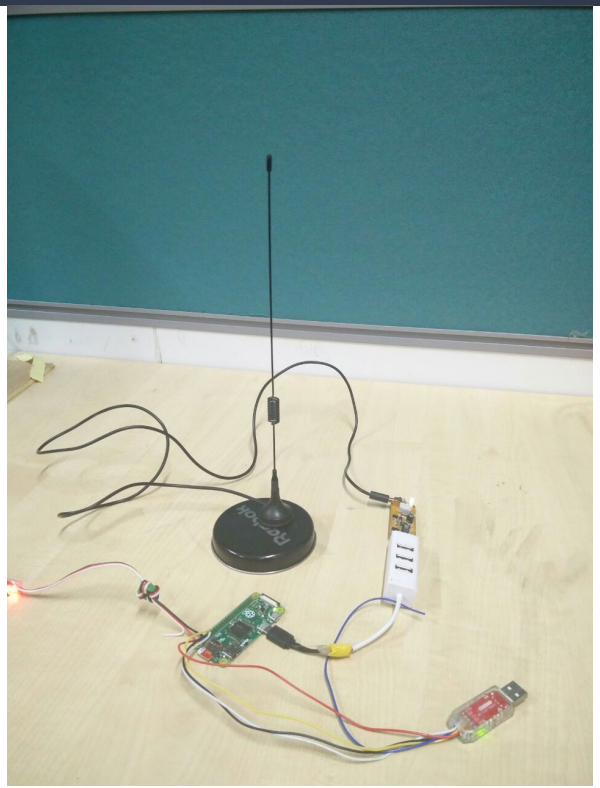
- Monitoring Police Walkie Talkie Spectrum
- Bandwidth of Dongle used = 2.76 MHz
- Decimated by 15
- RF Samples at 5.52 MSPS
- 9 point fft once per second
- Segregate into 9 bins of 23KHz each
- Starting freq = 859.916 MHz
- End freq = 860.123 MHz

Data

```
2018-03-09, 20:26:49, 859916000, 860100000, 23000.00, 141795, -7.28, -2.73, -9.64, -10.41, -13.54, -13.54, -13.38, -12.43, -12.43
2018-03-09, 20:26:50, 859916000, 860100000, 23000.00, 346725, -6.90, -2.24, -9.63, -10.11, -13.40, -13.40, -13.28, -12.25, -12.25
2018-03-09, 20:26:51, 859916000, 860100000, 23000.00, 347760, -6.60, -2.02, -9.51, -9.65, -12.44, -12.44, -12.20, -11.61, -11.61
2018-03-09, 20:26:52, 859916000, 860100000, 23000.00, 346725, 3.02, -0.58, -5.70, -6.53, -7.10, -7.10, -6.45, -2.78, -2.78
2018-03-09, 20:26:53, 859916000, 860100000, 23000.00, 347760, -6.60, -2.01, -9.71, -12.80, -12.97, -12.97, -12.67, -11.78, -11.78
2018-03-09, 20:26:54, 859916000, 860100000, 23000.00, 346725, -6.21, -1.63, -9.41, -12.44, -12.74, -12.74, -12.35, -11.39, -11.39
2018-03-09, 20:26:55, 859916000, 860100000, 23000.00, 347760, -5.77, -1.13, -8.95, -12.23, -12.45, -12.45, -12.13, -11.16, -11.16
2018-03-09, 20:26:56, 859916000, 860100000, 23000.00, 347760, -4.00, -1.12, -8.91, -11.88, -11.92, -11.92, -10.95, -5.85, -5.85
2018-03-09, 20:26:57, 859916000, 860100000, 23000.00, 346725, -1.15, -1.02, -8.48, -10.91, -10.57, -10.57, -8.61, -0.99, -0.99
2018-03-09, 20:26:58, 859916000, 860100000, 23000.00, 346725, 1.49, -0.79, -7.06, -9.72, -8.94, -8.94, -6.33, 2.30, 2.30
2018-03-09, 20:26:59, 859916000, 860100000, 23000.00, 346725, 2.03, -0.41, -6.75, -9.37, -8.59, -8.59, -5.86, 2.86, 2.86
2018-03-09, 20:27:00, 859916000, 860100000, 23000.00, 347760, -3.08, -1.46, -9.48, -11.80, -11.58, -11.58, -10.23, -3.56, -3.56
2018-03-09, 20:27:01, 859916000, 860100000, 23000.00, 346725, -6.61, -1.97, -10.11, -12.84, -13.05, -13.05, -12.67, -11.84, -11.84
2018-03-09, 20:27:02, 859916000, 860100000, 23000.00, 347760, 2.09, 0.14, -5.09, -6.46, -6.56, -6.56, -5.99, -1.51, -1.51
2018-03-09, 20:27:03, 859916000, 860100000, 23000.00, 346725, -6.28, -1.73, -9.91, -12.85, -13.05, -13.05, -12.24, -9.99, -9.99
2018-03-09, 20:27:04, 859916000, 860100000, 23000.00, 347760, -6.41, -1.90, -9.53, -12.84, -12.97, -12.97, -11.88, -9.43, -9.43
2018-03-09, 20:27:05, 859916000, 860100000, 23000.00, 348795, -6.50, -1.99, -9.91, -12.31, -12.89, -12.89, -11.53, -8.71, -8.71
2018-03-09, 20:27:06, 859916000, 860100000, 23000.00, 346725, -6.28, -1.76, -9.60, -9.42, -12.43, -12.43, -11.32, -8.27, -8.27
2018-03-09, 20:27:07, 859916000, 860100000, 23000.00, 346725, -6.30, -1.79, -9.51, -9.29, -12.39, -12.39, -11.24, -8.18, -8.18
2018-03-09, 20:27:08, 859916000, 860100000, 23000.00, 347760, -6.35, -1.81, -9.45, -9.51, -12.30, -12.30, -11.13, -8.16, -8.16
2018-03-09, 20:27:09, 859916000, 860100000, 23000.00, 346725, -6.44, -1.85, -9.49, -10.68, -12.67, -12.67, -11.90, -9.79, -9.79
2018-03-09, 20:27:10, 859916000, 860100000, 23000.00, 345690, -6.37, -1.83, -9.75, -12.77, -12.84, -12.84, -11.47, -8.59, -8.59
2018-03-09, 20:27:11, 859916000, 860100000, 23000.00, 346725, -6.36, -1.78, -9.78, -12.86, -12.94, -12.94, -11.71, -9.18, -9.18
2018-03-09, 20:27:12, 859916000, 860100000, 23000.00, 345690, 2.02, 0.24, -5.05, -6.53, -6.55, -6.55, -5.88, -1.29, -1.29
2018-03-09, 20:27:13, 859916000, 860100000, 23000.00, 347760, -5.91, -1.31, -9.35, -12.49, -12.63, -12.63, -11.71, -9.32, -9.32
2018-03-09, 20:27:14, 859916000, 860100000, 23000.00, 346725, -6.79, -2.33, -10.24, -12.70, -12.77, -12.77, -11.83, -9.44, -9.44
```

Hardware and Data Collection

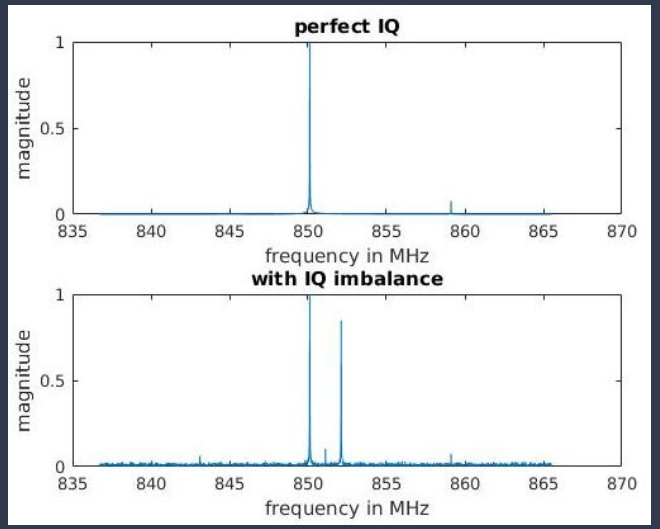
1. RTL-SDR (Register-Transfer Level Software Defined Radio) - This is a device which could be plugged into our computer to scan and read radio signals in the area. It can receive frequencies varying from about 500 KHz to 1.7 GHz. We have used RTL-SDR in our project to read and scan police walkie-talkie signals.
2. We have used RTL-SDR to collect police walkie-talkie spectral data from several places. Our data was acquired using a dongle of bandwidth 2.76 MHz. This was decimated by 15 and further sampled at 5.52 MSPS. We then applied 9 point FFT once per second and segregated it into 9 bins of 23 KHz each. The starting frequency of our data was 859.916 MHz and end point was 860.123 MHz. Thus, we had a band of 207 KHz (23 KHz * 9 = 207 KHz).

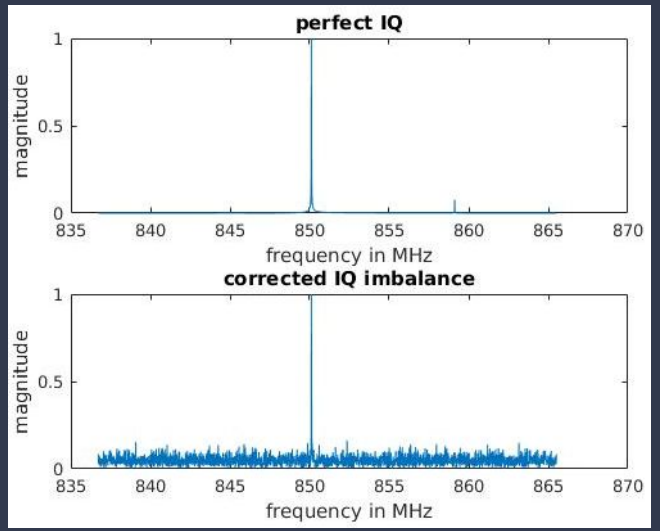


Probability Distributions Mapped

IQ Imbalance

This is the method for correcting the gain and phase imbalances and the bias errors of the in-phase (I) and quadrature (Q) channels of a coherent signal processor.





KL Divergence

Kullback-Leibler divergence is a method of understanding how a given probability distribution might be different from the expected probability distribution. It makes use of information theory to calculate the divergence. It calculates a number between 0 and 1 where 0 implies very similar (if not the same) probability distribution and 1 implies the opposite or very dissimilar. It differs from the distance concept. The KL divergence of A to B is not same is the KL divergence from B to A.

Data Analysis

Results

We tried to fit various combinations of Probability distributions like :- a) Rayleigh
b) Exponential functions c) Rice distribution etc which were single parameter functions only.

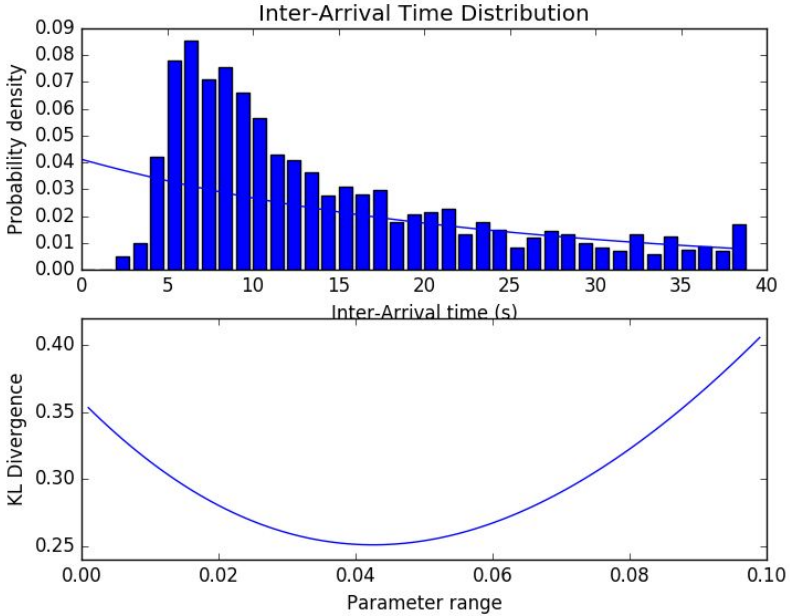
We got the best results in Rayleigh scattered PDF, while Exponential showed a bit of similarity too.

We used to theory of KL Divergence which uses predictive maths to find the minimum difference between any two distributions. [Theory explained in another slide].

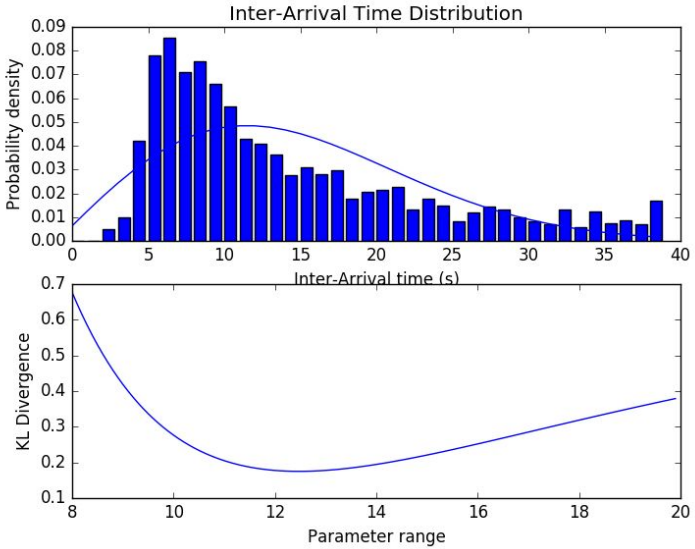
We created an algo, which would take in the range of the distribution parameters and plot the KL-Div isto parameter range graph. Subsequently detecting the lowest KL-Div point which would give us the best distribution B that fits our distribution A.

We then plot a histogram and Best-Fit-Distribution on the same axis to showcase the resemblance.

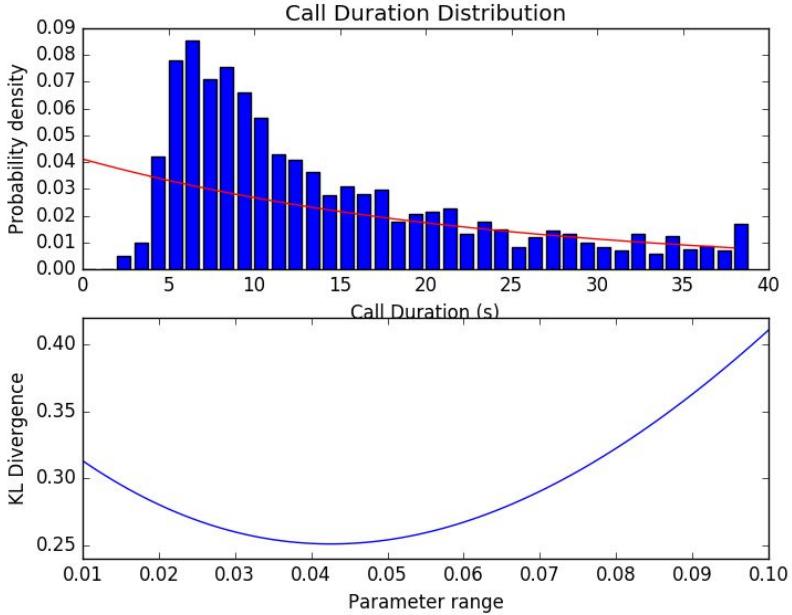
Exponential(lambda=0.018)



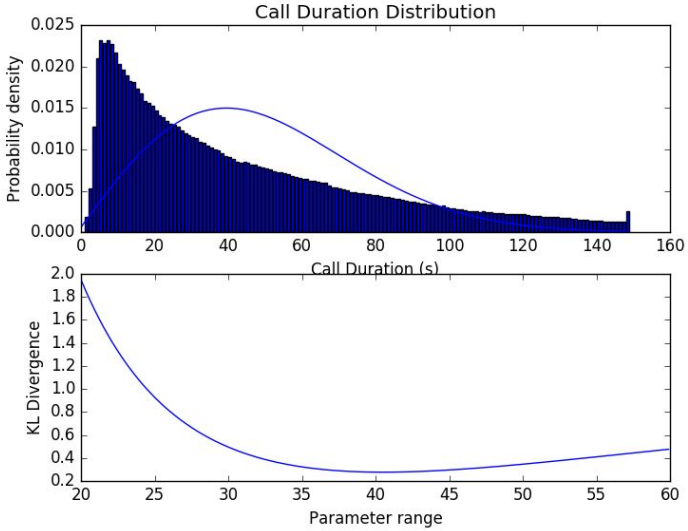
Rayleigh(sigma=12.47)



Exponential(lambda=)



Rayleigh(sigma=)



FSM for prediction