Rapport de Labo5

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1 Introduction

The goal of this lab was to detect the beginning of the signal we are interested in by using a training sequence as well as compensating the frequency offset that could occur if the signal is downconverted with a different carrier frequency than the upconvert.

2 Pre-Lab

2.1 Describe what happens to the error rate of your system when the estimate for the delay in the channel is off by more than one symbol time (noise power of 5db and no frequency offset correction)

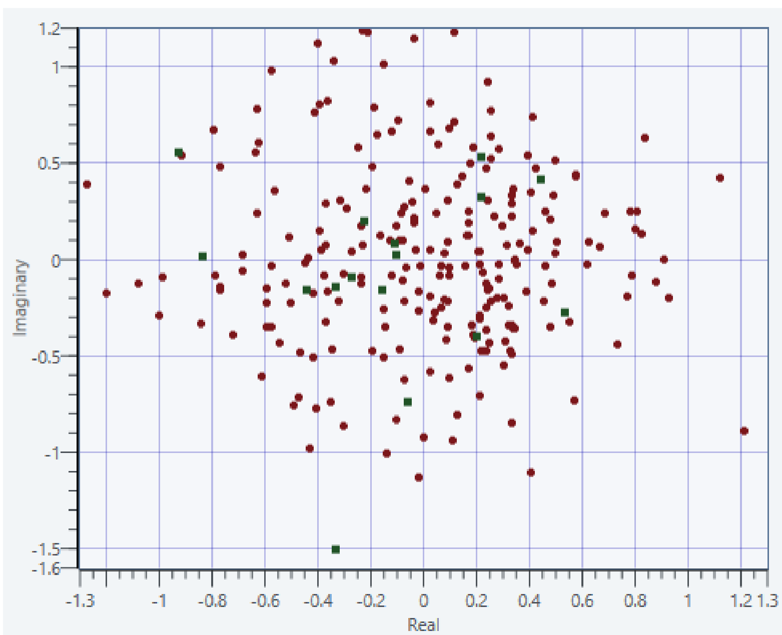

Figure 1: Constellation for AWGN , with noise 5db

The AWGN adds noise to the signal so the correlator has a harder time to correct the frequency offset and to find the actual frame. The data are spread out on the constellation. This induce a big BER.

2.2 What happens when there is a frequency offset of 201Hz if you do not correct it?

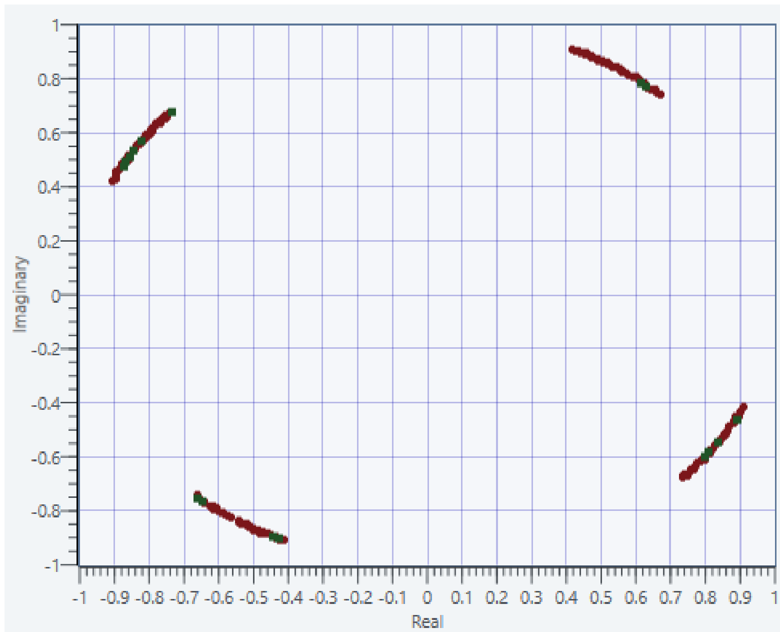

Figure 2: Constellation with Frequency offset of 201 Hz

The offset in the frequency in between the upconvert and downconvert will induce a phase shift in the symbols; there is $f = \frac{d\phi}{dt}$. The real and imaginary parts vary through time and because we don't correct it we have symbol values which are not well detected by the system.

2.3 What are the range of frequency offsets that you can estimate/correct using Moose algorithm?

c The range of frequency offsets that you can estimate with the moose algorithm is $|f_e| < \frac{1}{2TN_s} = 22.727kHz$. This frequency bound comes from the fact that to resolve correctly the phase shift between training sequences, and then perform a good comparison between them, this phase shift has to between $[-\pi, \pi]$. If it's greater, even if we correct the offset, we would be comparing different indices.

2.4 Set the frequency offset to FALSE. What happens to the received constellation for different values of the frequency offset?

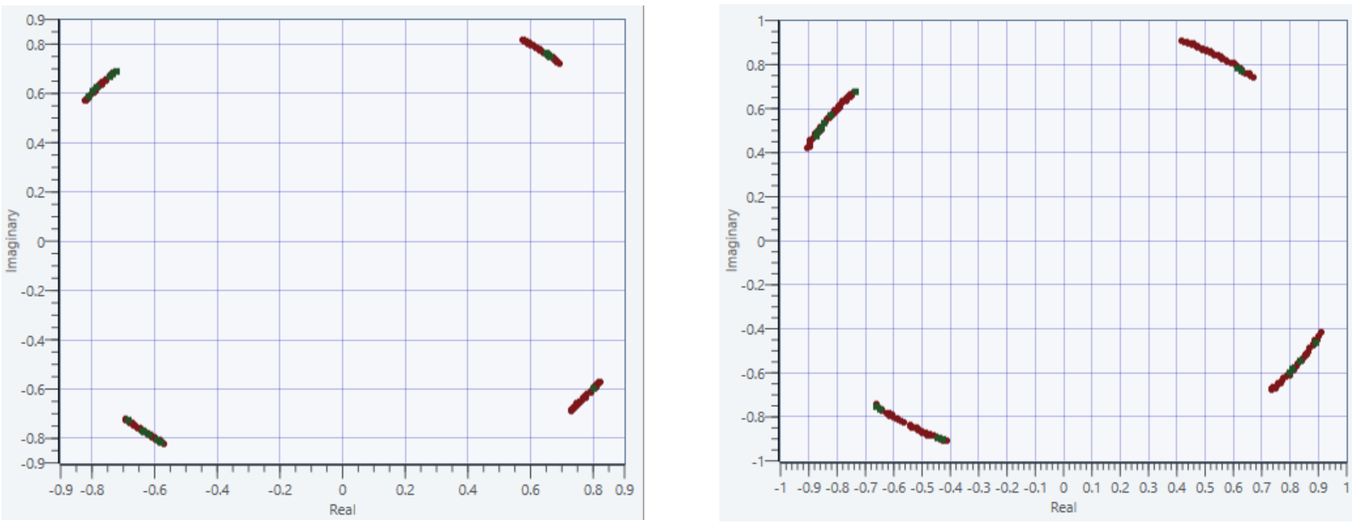

Figure 3: Constellation with Frequency offset of 100 Hz and 201 Hz

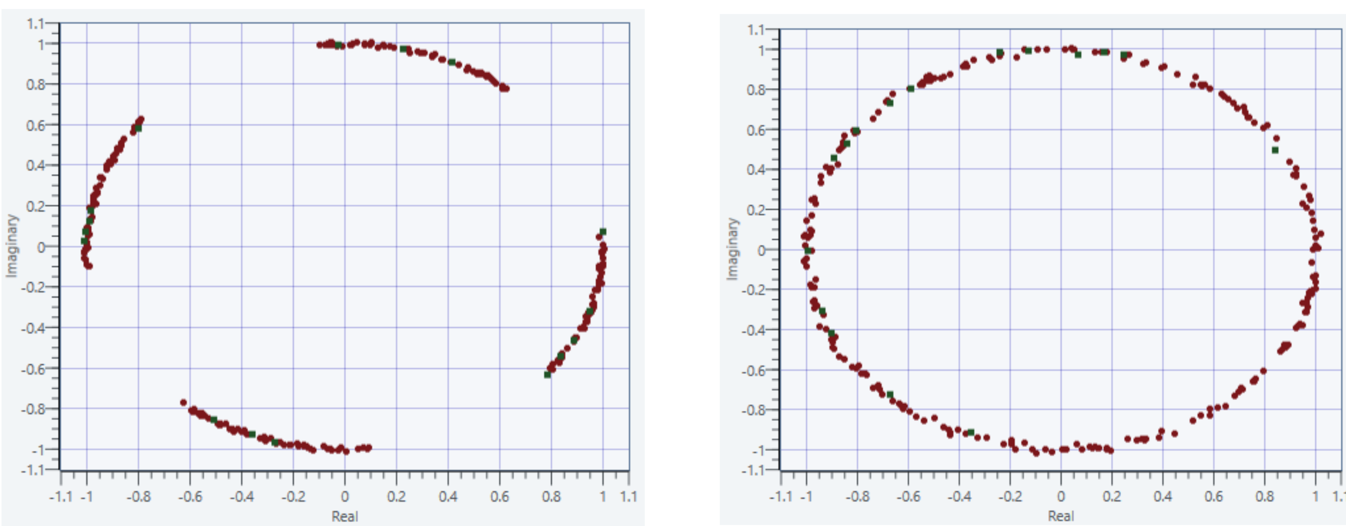

Figure 4: Constellation with Frequency offset of 500 Hz and 1000 Hz

The phase shift increases as the frequency offset also increases, as expected ($f = \frac{1}{2\pi}\frac{d\phi}{dt}$). So for the same delay, a higher offset will make the phase shift more.

2.5 Set the frequency offset to TRUE. Select the self reference with power normalization method. What is the limit for the frequency offset? Is this consistent with the theory?

The algorithm fails right above the theoretical value computed of 22.727 kHz.

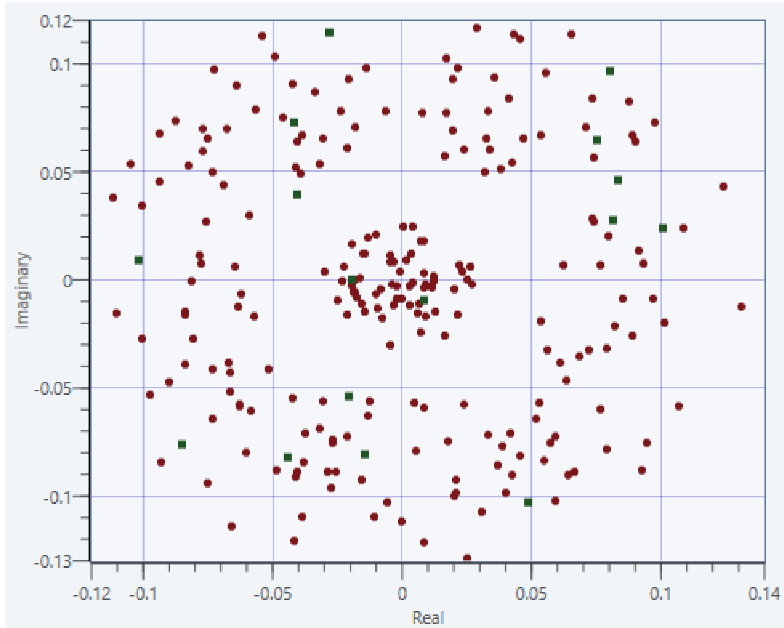

Figure 5: Constellation with Frequency offset of 22.728 kHz

2.6 Using the sliding correlator that you implemented, what is the limit this time? Why?

It can correct up to 10.943 kHz. But this experimental value may vary due to the random training sequence. This does not reach the theoretical value, this is due to the fact that the frame detection algorithm is failing before the theoretical 22.727 kHz value. When the frequency offset increases the cross correlation between the training sequence and the signal doesn't give a good maximum. The maximum is not observable anymore and actually goes below the amplitude of another index, which will be wrongly picked.

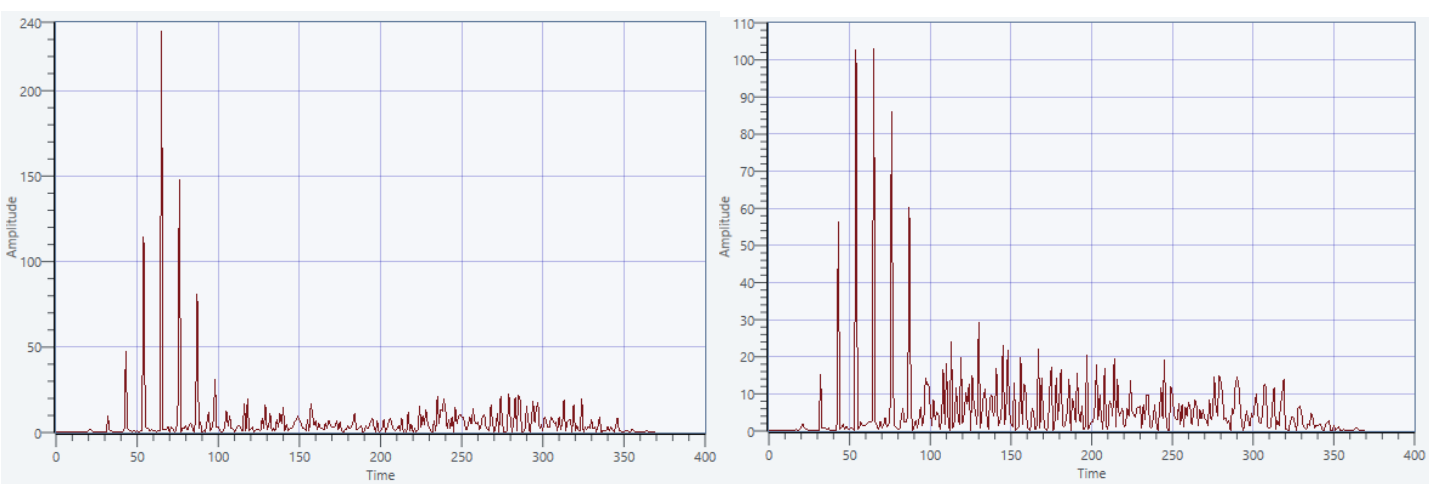

Figure 6: Auto-Correlation with Frequency offset of 1 kHz and 10.943 kHz

The frame detection will not function properly if the symbols are corrupted, which means if they are shifted for $\frac{\pi}{4}$ or more, this is because the symbols will not be mapped correctly on the receiving end.

Given that the frequency offset is constant, which is here the case, and knowing that $\omega = \frac{d\phi}{dt}$, we can say that

$\phi = \omega t$. Therefore we have :

$$f = \frac{\frac{\pi}{4}}{2\pi 1.10^{-5}} = 12.5kHz. \quad (1)$$

This value gives the frequency limit for the frame detection and then the limit for the all sliding correlator.

3 Lab

3.1 Calculate an average value (using five runs or so) of the inherent offset between the transmitter and receiver

The average value is 11.88 Hz for a carrier frequency of 144MHz. This value is really small, it then performs a good detection. It is non zero due to the imperfection of the hardware.

3.2 Based on the system parameters, what is the range of frequency offsets that can be estimated by your frequency offset estimation algorithm?

The implementation can estimate the frequency offset up to $|f_e| < \frac{1}{2TN_s} = 4.545kHz$

3.3 Let f_m be the maximum correctable frequency offset of your system (i.e., as calculated in the previous question).What is the ratio between f_m and the carrier frequency? Comment. How does this compare with values associated with practical hardware?

The carrier frequency is 144 MHz. We have a ratio of $\frac{f_m}{f_c} = 3.15 * 10^{-5}$ which means that the maximum offset can be up to 0,00315% of the carrier frequency. This ratio quantifies how far from the carrier frequency the offset can be before the failure of the algorithm. For instance with another USRP of carrier frequency of 1990 MHz gives a ratio of $\frac{f_m}{f_c} = 2.28 * 10^{-6}$ which is 0.00002%. As the carrier frequency increases the phase shift for a similar delay is more important, inducing bigger errors.

With a carrier frequency of $144 * 10^6$, by applying different offset we can find that the cut-off frequency is 2191 Hz. This is for USRP that are linked through cables, which means they share a similar clock. The ratio in this case is $1.52 * 10^{-5}$. It's lower than the one found previously. This is again due to the collapse of the frame detection method. Another technique can be used by using a transmitter and receiver which are designed for different carrier frequencies.

3.4 How does this frequency offset impact the performance of your correlation based frame detector (i.e., does your correlation based detector still find the start of the frame)? Describe what happens to the error rate and constellation of your system.

By increasing the frequency offset it can be seen that the constellation rotates. The correlation based detector can find the start of the frame up to a certain offset, here 2191 Hz. At this point, the error rate become 0.5. The constellation also become spreaded out.

4 Additional questions

4.1

-The fact that the clock of the receiver and transmitter are not synchronised, if not connected by cable. -Shadowing. - A too important frequency Offset -ISI

4.2

The first approach was to consider the frequency offset as null to calculate the frame delay, it was found by using the strong autocorrelation properties of training sequences. In reality, real wireless channels can result in large frequency offset. This induce a phase shift of the symbol through time, and then a phase shift in between the two training sequences. If the phase shift is too big ($\pi/4$) the symbols aren't well detected, the two training sequence compared aren't the same anymore and the frame detection doesn't work. To resolve this problem we perform frame detection by taking into account a possible offset and by correcting it with Moose algoritm while performing frame detection. This operation is made by self referenced frame detection

4.3

The channel can possibly induce a strong attenuation, represented by α, if the attenuation is too big the entire signal can start to compete with noise, which could modify the shape of our signal and then the correlation. By keeping the autocorrelation strong we can reduce this effect.

5 Conclusion

The algorithms used in this lab are efficient up to a certain frequency offset, after that they collapse, it possible to use other algorithms that are more resistant to counter the effect of that offset.