Rapport de Labo4

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1 Introduction

The main goals of this laboratory is to use linear least square estimation and linear equilization to mitigate channel distorsion due to multipaths in the propagation environment. A theoretical channel is first used to see the impact of the equalizer length on the BER. Then, the channel is tested over a real wireless link for two different cases: a narrowband channel and a wideband channel. For these, typical values are calculated and observed such as symbol rate, bandwith and power-delay. The effects of the channel on the constellations are also examined.

2 Pre-Lab

2.1 Toeplitz matrix

In a Toeplitz matrix, the first row and fist column element should be equal. A premade special bloc was used in our implementation called "Special Matrices".

2.2 Test of the equalizer algorithm

The implementation of the equalizer algorithm was tested by modifying the equalizer length from 1 to 6 in absence of noise. The constellations were then analyzed for a length of 1 ,3 and 6.

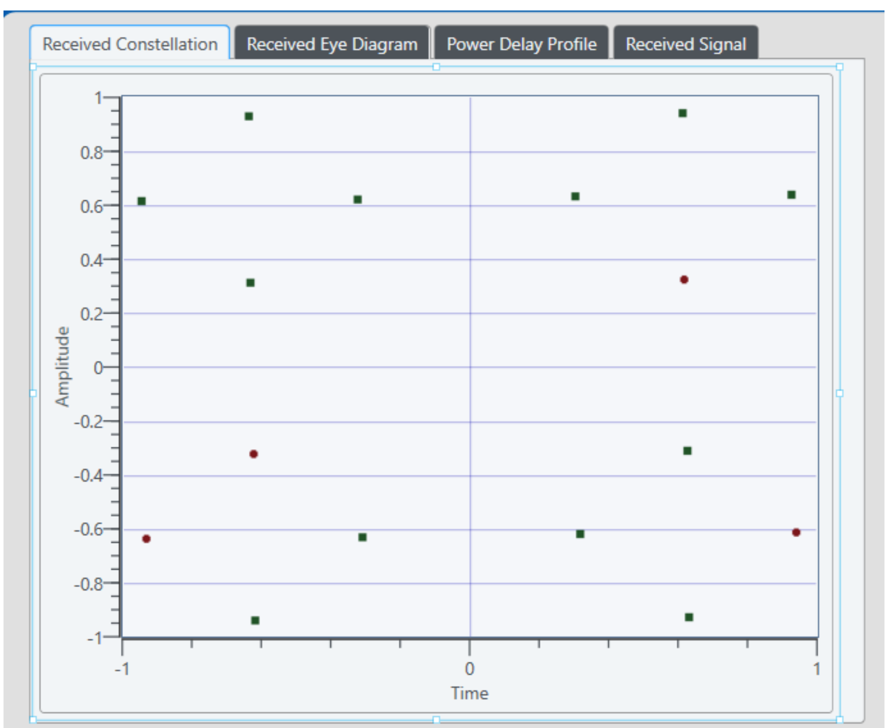

Figure 1: Constellation for L_f+1=1

As it can be seen the constellation is improving drastically as the length of the 'test sequence' increases. The constellation is getting nearer and nearer to the true symbol values. When this test sequence is too small , with have too few degrees of freedom to find the coefficiants that would be used in the equalizer. As shown in figure 1, with a test sequence of one symbol it only has one degree of liberty available and this doesn't provide good results.

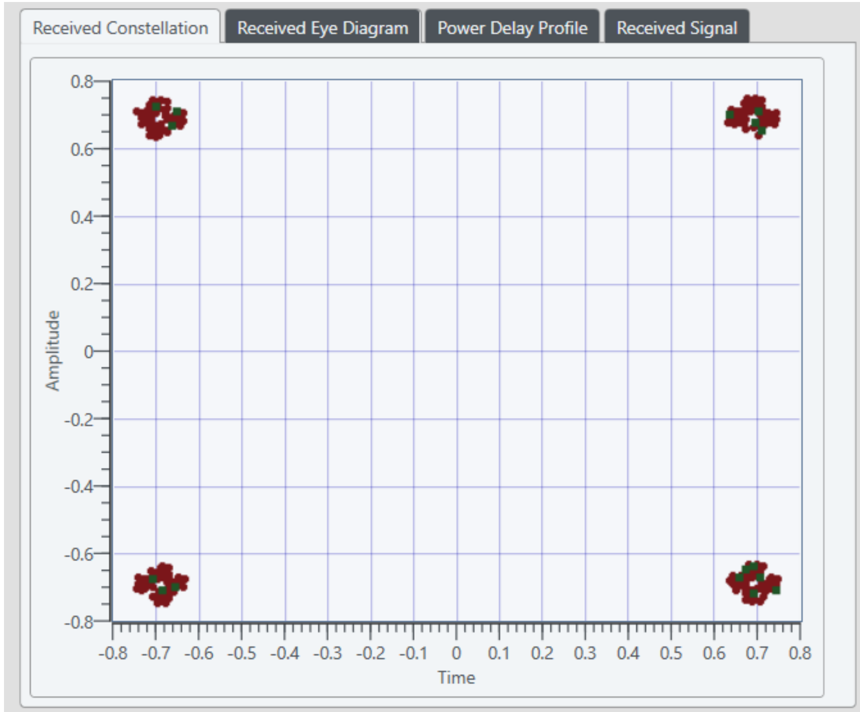

Figure 2: Constellation for L_f+1=3

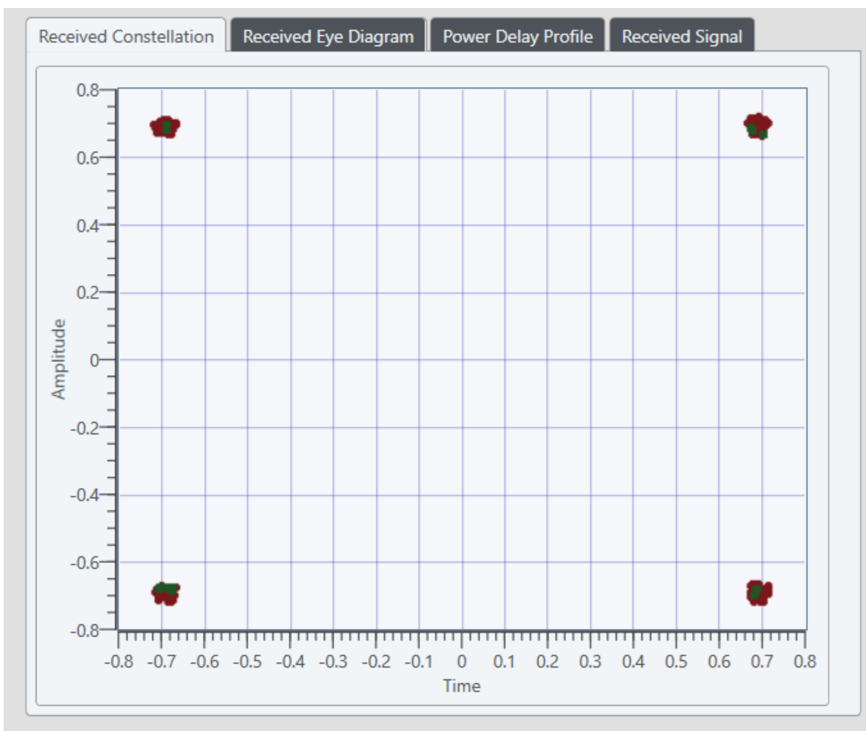

Figure 3: Constellation for L_f+1=6

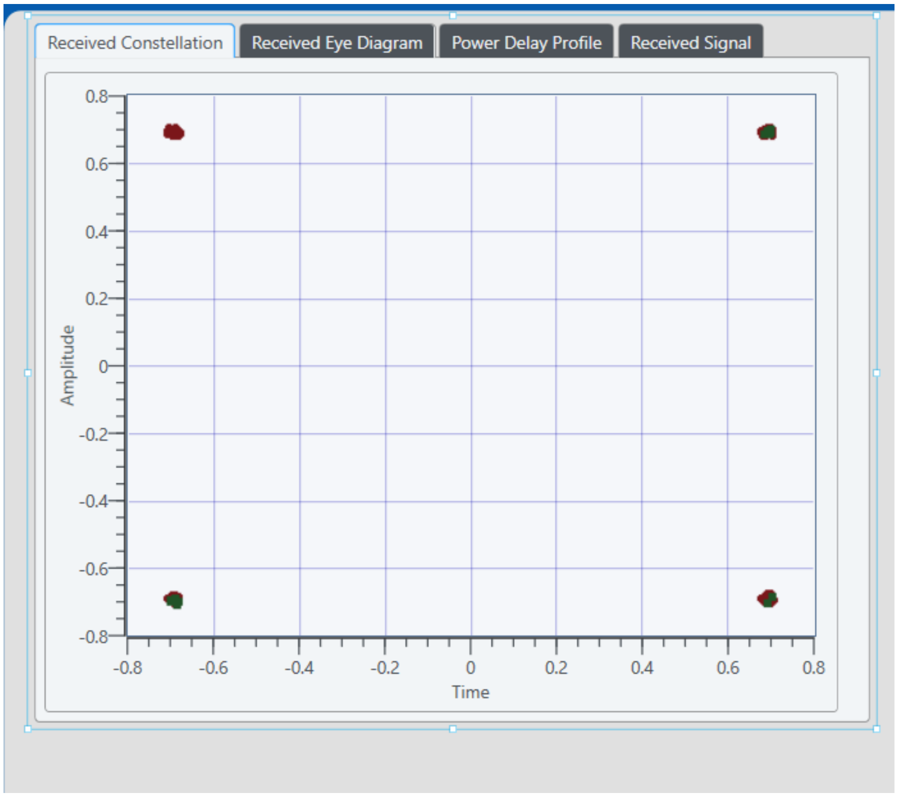

Figure 4: Constellation for L_f+1=8

We decide to take this point further and tried our algorithm with even more symbol in our test sequence. We realised that the precision of the method increases until a certain point where it starts collapsing (aroud $L_f + 1 = 10$), we believe it is due to the fact the matrices is becoming too complex mathematically to be properly computed/solved. Figure 1, 2, 3 and 4 are related to the increase of the precision of our constellation and 5 and 6 show the values of $L_f + 1$ for which the precision decreases.

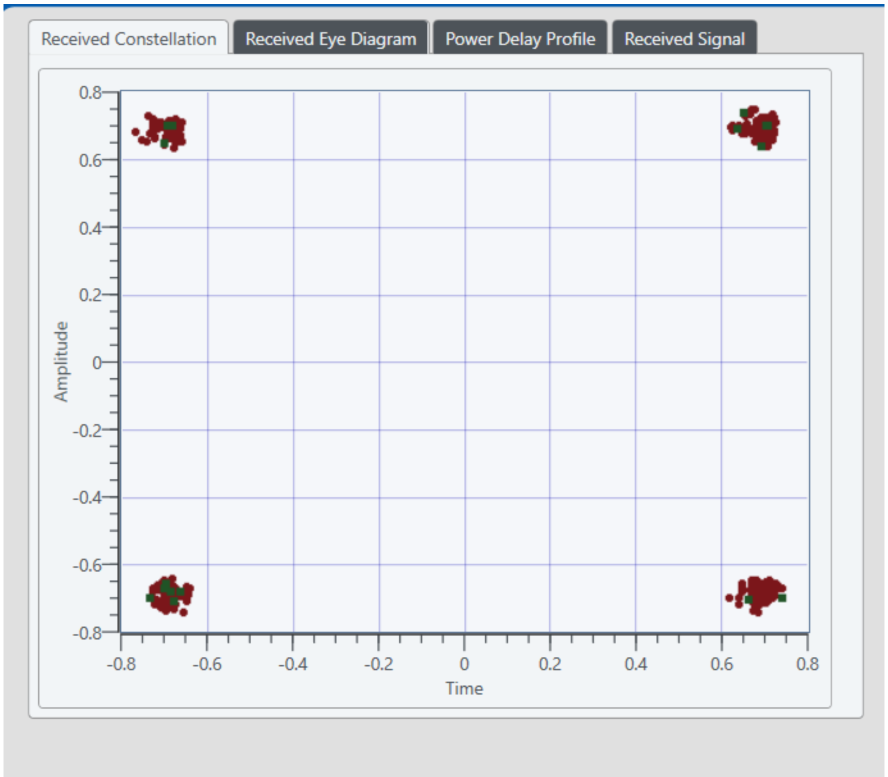

Figure 5: Constellation for L_f+1=10, the method starts collapsing

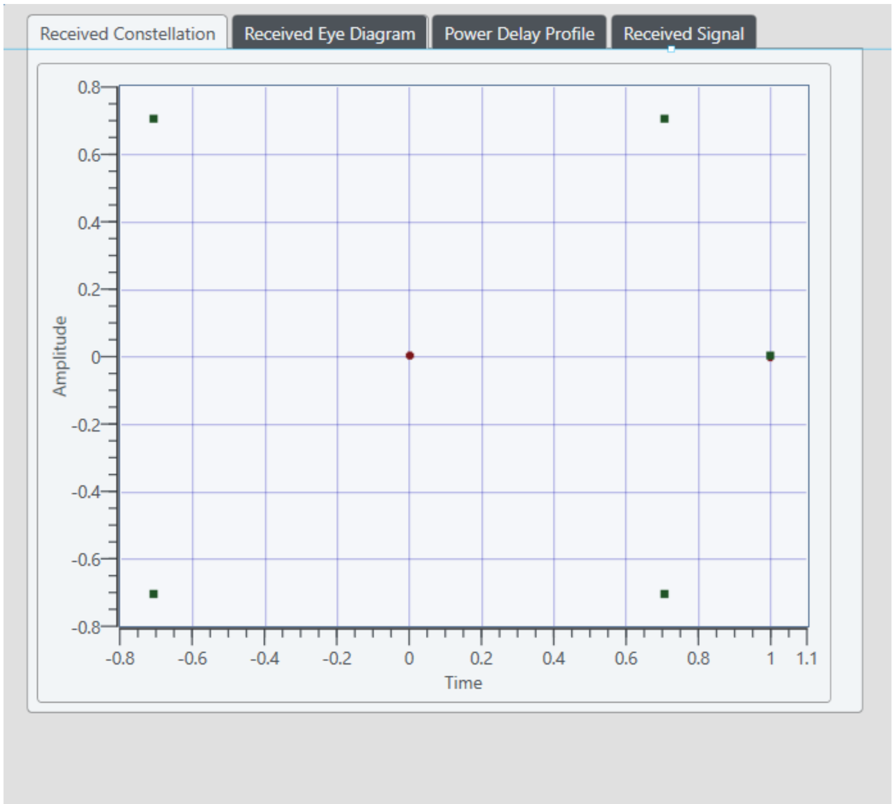

Figure 6: Constellation for L_f+1=12, total collapse of the method

2.3 BER and SNR

In this section, the behaviour of the BER compared to the SNR is analyzed when the noise decreases from 0db to -14 dB with a decrement of 2 dB. The signal is assumed to be 0 dB. Then a decrement of 2dB in noise result in an increment of 2 dB for the SNR. It can be noticed thanks to figure 7 that even though the two curves are pretty similar, the values of SNR and BER are decreasing faster for $L_f + 1 = 6$ compared to $L_f + 1 = 1$ when decreasing the noise. This makes the channel with $L_f + 1 = 6$ more efficient in term of BER.

We can say that the channel is therefore more efficient for higher values of Lf because the BER decreases but there's also a compromise with higher value of Lf because of the complexity of calculation for the implementation.

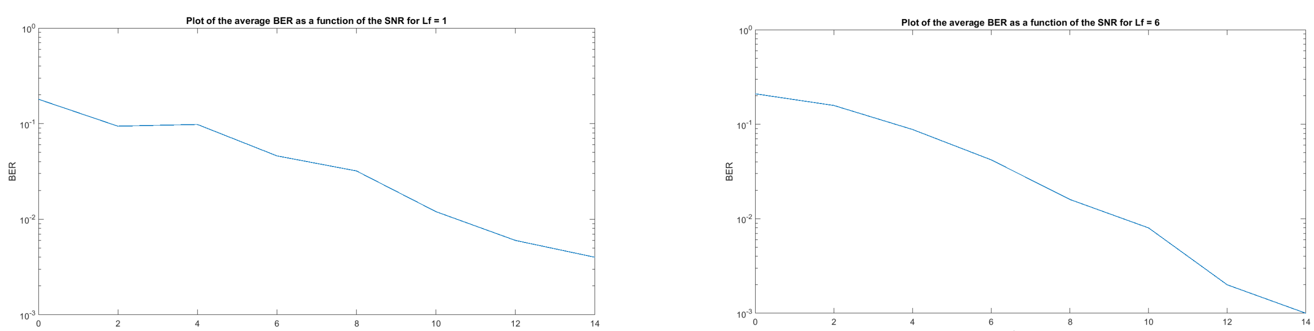

Figure 7: Plot of the BER with regard to the SNR for $L_F + 1 = 1$ and $L_F + 1 = 6$

3 Lab

3.1 Narrowband and Wideband communication

Figure 8 shows a graphical representation of the spectrum for narrowband and wideband signals in namesake channels. These two types of channels have different features. Narrowband systems have a small bandwith while wideband systems have a larger bandwith. Because wideband systems work with larger bandwith it also include a non negligible noise. Then, to compete with this noise and have a good SNR, the power of the signals has to be more important. The fact that a bigger bandwith is used also result in more power consumption. Because wideband systems operate on a larger bandwith they permits to increase the informations sent through the channel compared to narrowband channels.

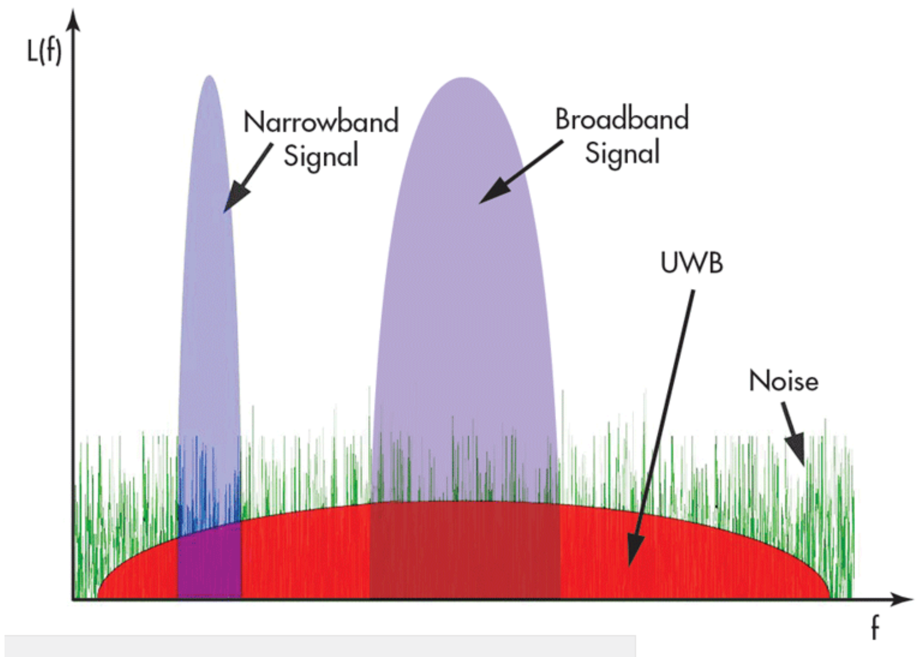

Figure 8: Schematics representation of the spectrum for different types of transmission including narrowband and wideband signals

3.2 Narrowband Channel

3.2.1 Symbol Rate

In this case the channel is transmitting and receiving 100 000 symbol/sec.

3.2.2 Passband Bandwith

By applying Shannons's general theorem we know that $f_{Sampling} \geq 2f_{max}$. In this case, it can be said that f_{symbol} is linked to the bandwidth B by the following relation:

$$f_{symbol} \geq 2B \tag{1}$$

Where B is the bandwith in Hz.It is important to include the Roll-Off factor α in the bandwidth B.Knowing f_{symbol} , B cannot be higher than 50 000 Hz.

3.2.3 Visualisation of the Channel Distortion

To be able to visualize the narrowband channel distortion, we ploted the constellation before getting in the equalizer and afterwards (figure 9). Without the equalizer, it is now actually a visualisation of the signal and the added training sequence. With those graphes, it was concluded that the channel is only having an influence on the phase of the signal and not the amplitude of it as the symbols appear to have the same module (same distance from 0). The phase impact can be visualized by the shifting/rotation of the constellation.

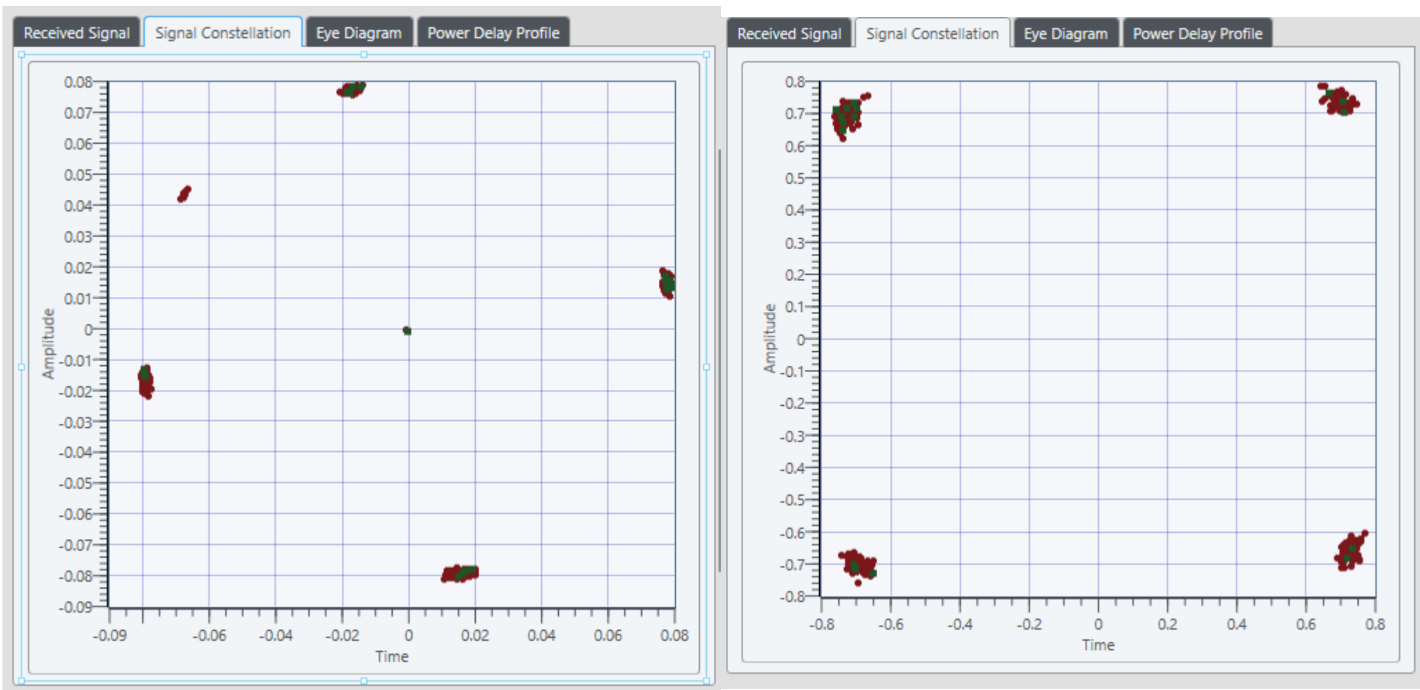

Figure 9: Comparison of the constellation without (left) equalisation and with it (right) for the same configuration

3.3 Wideband Channel

3.3.1 Symbol Rate

For this communication, the symbol rate of the system is $5 * 10^6$ symbol/sec.

3.3.2 Bandwith

Once again, by refering to equation 1,Shannon's theorem we can define the bandwitdh B. It is important to also include the Roll-off factor α.

3.3.3 Power-Delay Profile

As it was asked the power-delay profile of a wideband system was measured by settings the correct parameters for our channel. By averaging the power-delay profile over five operations the general power-delay profile of our system can be found. In this case it is given by figure 10.

It can be observed that most of the power is located near $\tau = 0s$. It actually decreases linearly from it's maximum value in $\tau = 0s$ up to $\tau = 0.1 * 10^6 s$ where its value is 0 W. Finally there's another increase in the power from $\tau = 0.1 * 10^6 s$ up to $\tau = 0.2 * 10^6 s$ and then another decrease from $\tau = 0.2 * 10^6 s$ up to $\tau = 0,3 * 10^6 s$. After $\tau = 0,3 * 10^6 s$ the power-delay profile remains 0W. The channel as clearly a linear distribution of the power over the delay.

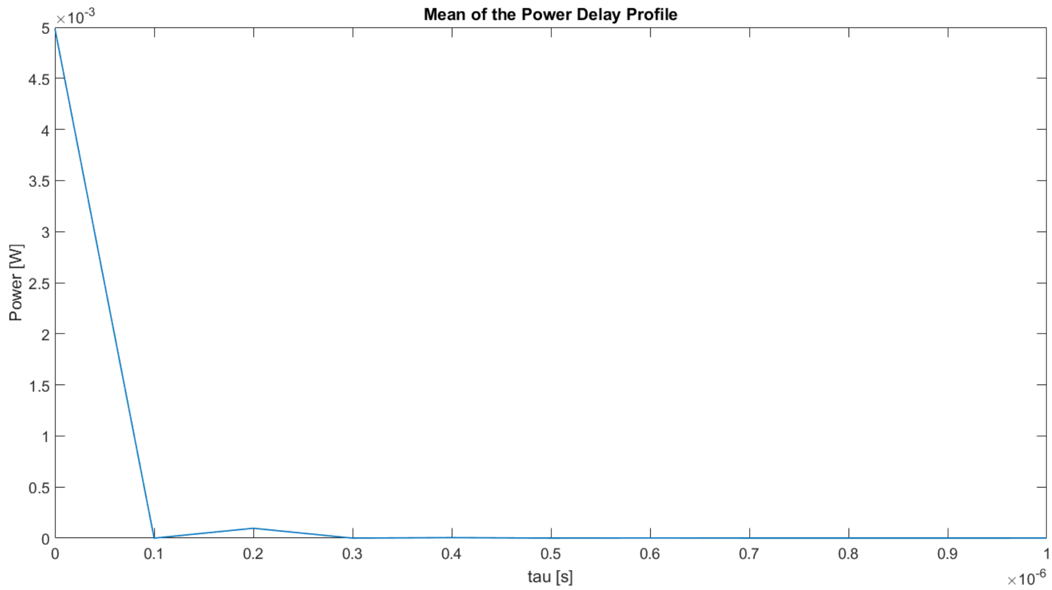

Figure 10: Power-delay profile of our system by setting the parameters to have a wideband channel

3.4 Additionnal questions

For each system, the number of elements for which the power is non zero is given by

$$elements = T_{system} * time \tag{2}$$

For the narrowband channel we have: $T_{nb} = 10^5$ and $time = 2.5 * 10^{-6}$ we then have 0.25 elements. For wideband channel we have: $T_{wb} = 5 * 10^6$ and $time = 2.5 * 10^{-6}$ we then have 12.5 elements.

Because we have $12.5 > 0.25$ the wideband channel can resolve the channel response more accurately. This is because the number of coefficients h[n] will be more important.

4 Conclusion

The equilization method using least mean square permits with additionnel hypotheses, as FIR filter, to mitigate the effect of multipaths propagation. The efficiency of our implementation increases with the length of the filter, as a result the BER decreases. But there's also a compromise for the length of the equilizer because values of Lf which are too big induce complex calculation and the implementation is not efficient anymore. There are also different kind of communication channels, narrowband and wideband channels. Even if wideband channels need a higher power consumption they permit to transmit more information because of larger wideband than narrowband. Wideband channels have also more elements h[n] for the same time window resulting in better least mean square performances.