IPSA - Engineering School

Radar signal processing: radar detection and tracking

Programming report

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Contents

I- Introduction

The purpose of this report is to simulate the detection capability of a radar by different methods of calculation and detection.

The first one is the « On-Off detection » defined by the formula:

$$\text{Pfa} = Q\left(\frac{\eta\sqrt{N}}{\sigma}\right)$$

$$\text{Pd} = Q(Q^{-1}(P_{FA}) - SNR)$$

Where:

$$Q(z) = \int_{z}^{+\infty} \frac{1}{\sqrt{2\pi}} e\left[-\frac{x^2}{2}\right] d_x$$

$$SNR = \frac{A}{\sigma^2 \,/\, N}$$

The Second one is the « The Adaptive Matched Filter (AMF) » defined by the formula:

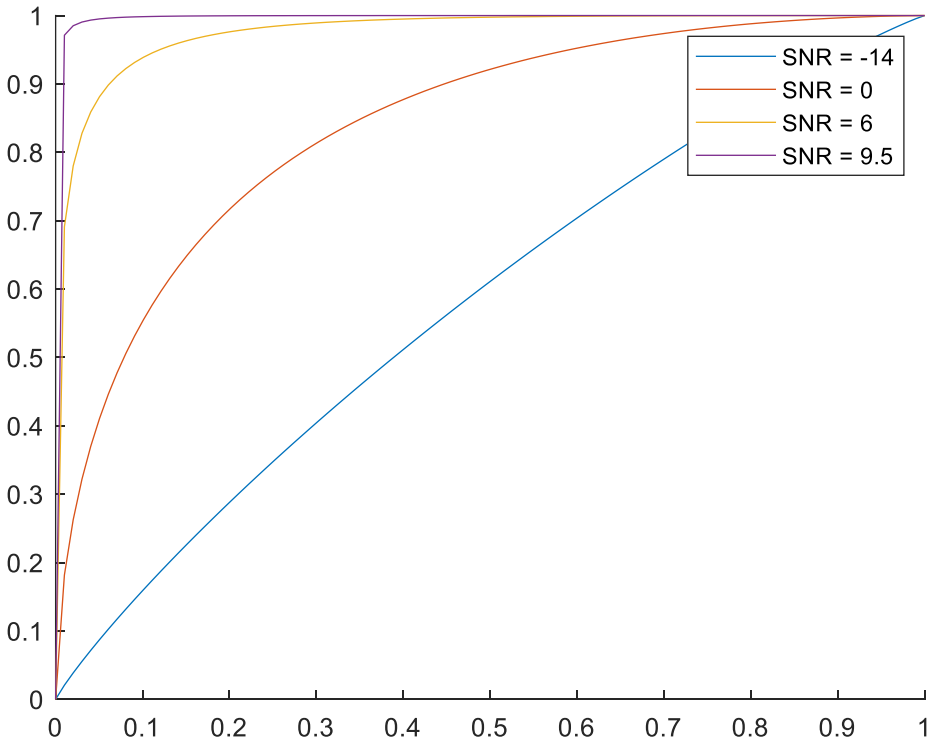
$$\Delta_{AMF}(z) = \frac{|P^H \hat{R}^{-1} z|^2}{P^H \hat{R}^{-1} p} \gtrless \lambda$$

The Third one is the « Kelly's Generalized Likelihood Ratio Test (Kelly's GLRT) » defined by the formula:

$$\Delta_{GLRT}(z) = \frac{|P^H \hat{R}^{-1} z|^2}{(P^H \hat{R}^{-1} p)(1 + \frac{1}{K} z^H \hat{R}^{-1} z)} \gtrless \lambda$$

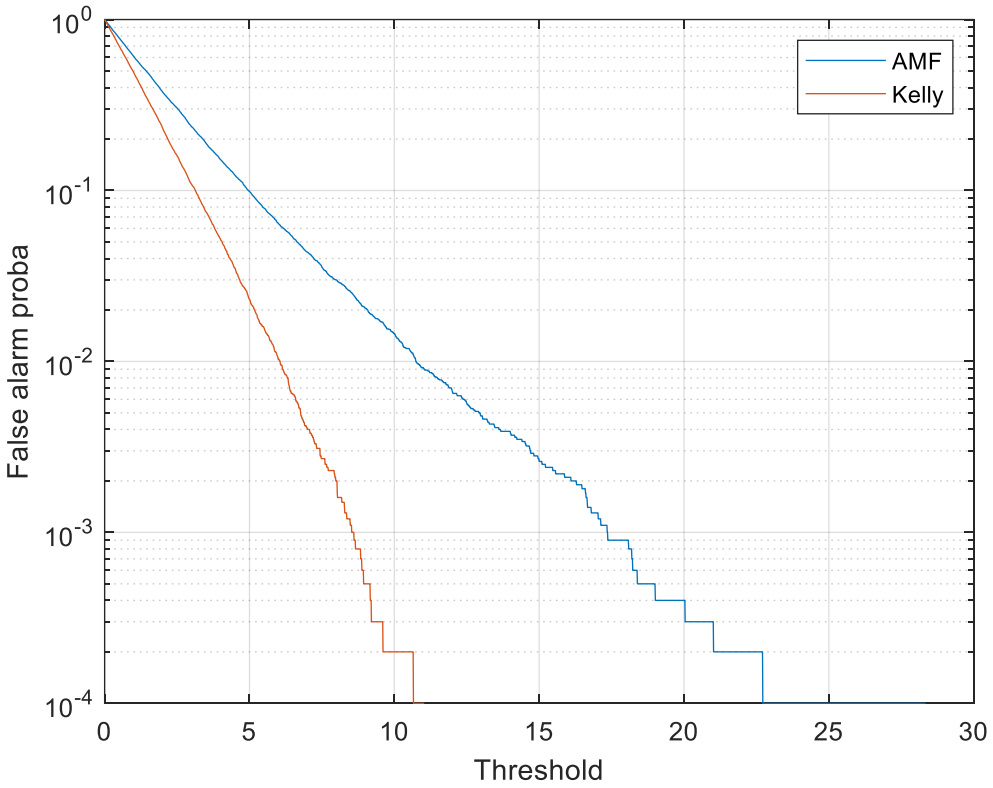
We notice that the AMF and the Kelly's GLRT method are similar, the only difference is the term on the denominator in the formula of Kelly's GLRT.

II- On-off detection simulation



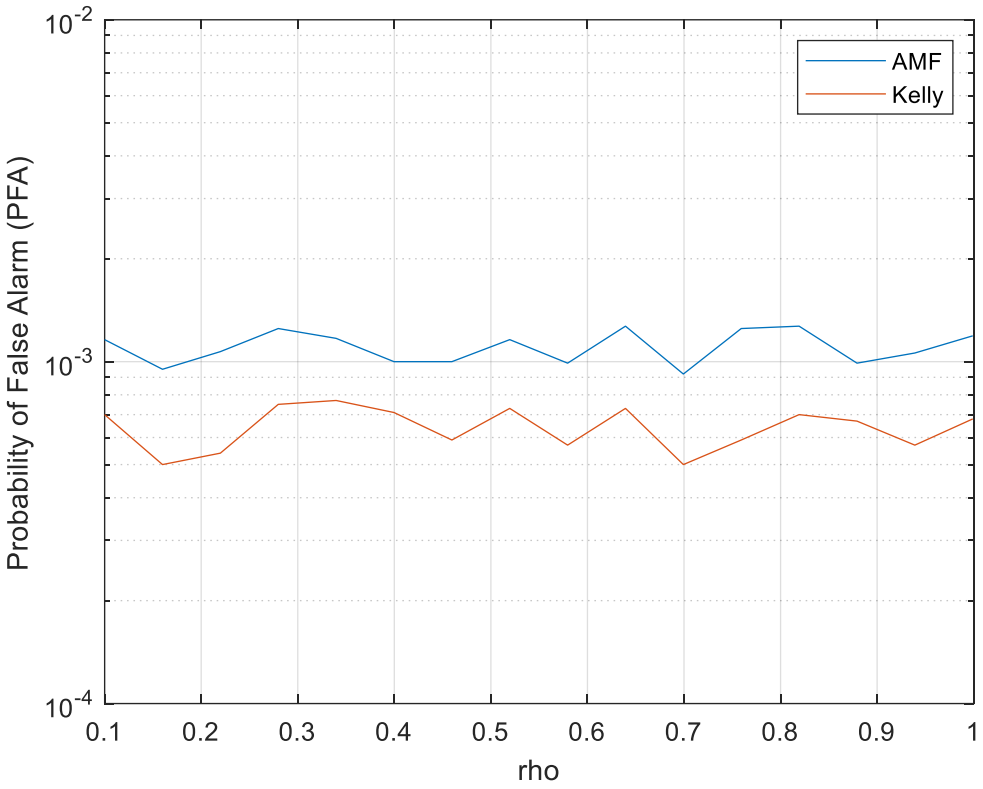
As we can see on the ROC (Receiver Operating Characteristics) of the On/Off detector, the assessment of the detector shows us that the maximization of the probability of detection is directly linked to the problem of maximization of the SNR (Signal-To-Noise ratio).

III- Probability of false alarm as function of the threshold



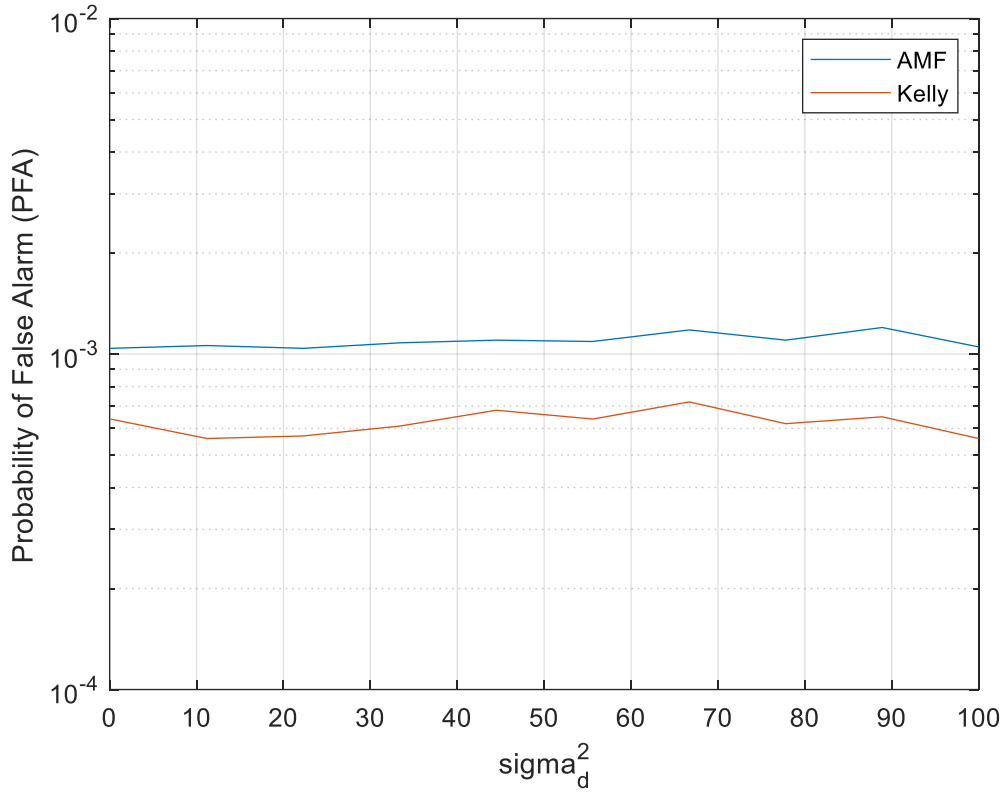
This figure allows us to have an idea of which method is decreasing its probability of false alarm the easiest when varying the threshold value. As we can see the Kelly's method is the better method here. It also helps us to find the value of the threshold for each method when we will fix the PFA value to 10e-3.

IV- Probability of false alarm as function of ρ, the correlation coefficient



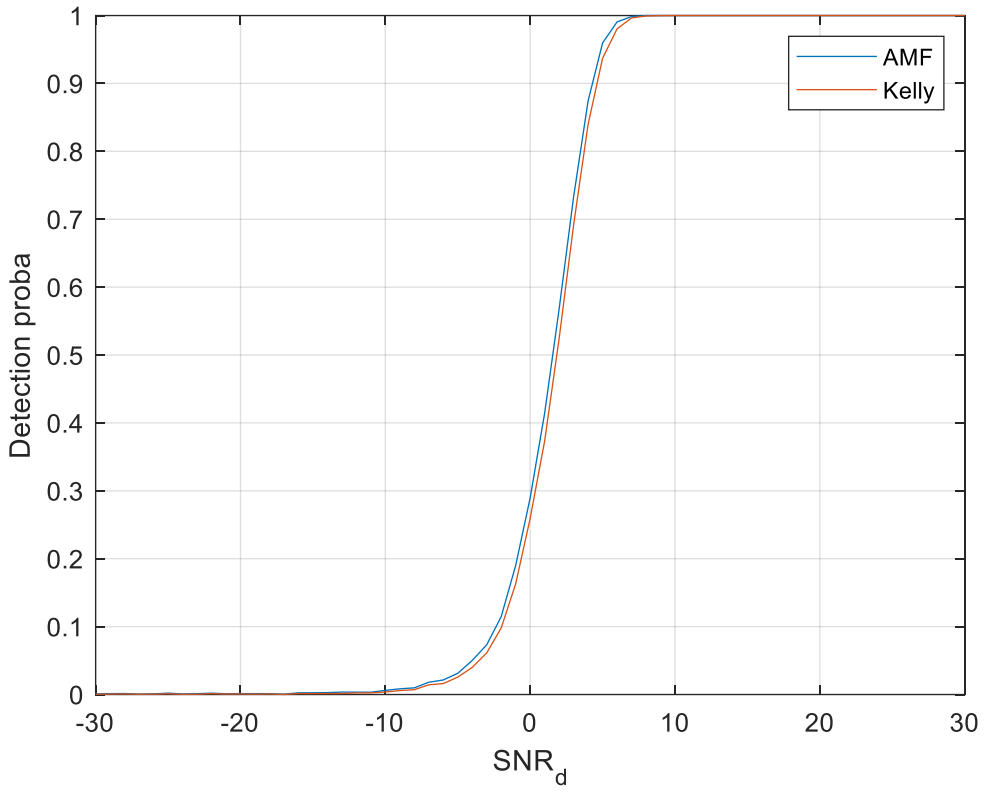
The term ρ influences the matrix C_d which is the matrix of the simplest clutter model that we assumed in our case, taking the Toeplitz structure. This term is one component of the methods AMF and Kelly's modelling the changes in the physical behaviour of the interference of an assumed radar measurement. By varying ρ from 0 to 1 we can observe that the PFA is constant. Its value oscillates around 10^{-3} in both methods. We can still notice that for the value settled at 10^{-3} have some margin error added to small variation of the PFA that are too small to invalidate the CFAR (constant False alarm Rate) property. We can then validate both methods CFAR properties.

V- Probability of false alarm as function of $\sigma^2_{d,}$ the noise power



As with previous the figure the σ_d^2 is variating when the rho value is fixed $(= 0.8)$ as well as PFA and we observe the same result within the case of AMF method less margin error with the set value of 10^{-3} of the PFA but much more margin error for the Kelly's method. Both methods are relatively constant, therefore we can validate again the CFAR property in this case as well.

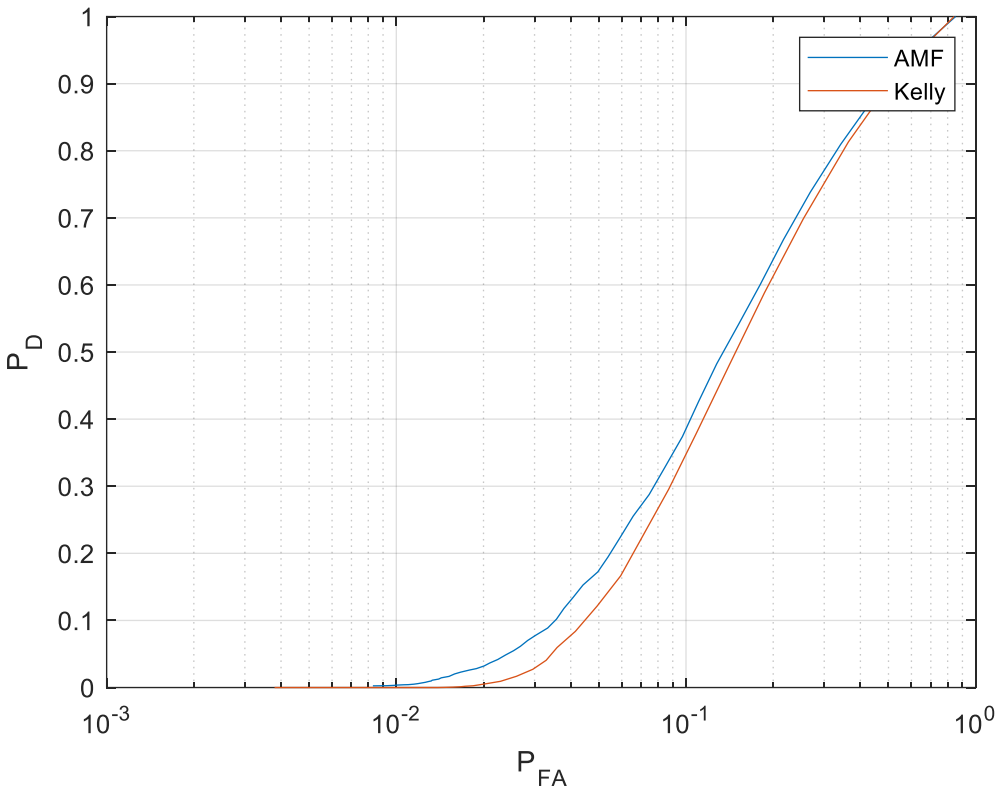
VI- Probability of detection as function of SNR



As seen in the on/off detector case, the maximization of the SNR is equivalent to maximizing the probability of detection. We can observe, in this figure, that for a SNR of 8 dB or more the probability of detection is maximized to the fullest. The figure as been made for threshold fixed at $\lambda_{AMF} = 17.42$ and $\lambda_{GLRT} = 8.53$ valued chosen for a fixed PFA at 10^{-3}. The σ_d^2 value is also fixed at 1.

Of course, for the cases where the SNR is below 0 dB the probability of detection is minimized because it would be the case where the detector receives more noise than actual accurate information.

VII- Roc Curves of AMF and Kelly



The following figure show us the assessment of the detection performance between both of our method AMF and Kelly. We notice a probable problem since the AMF probability of detection is superior to the Kelly method. We suppose that the problem may occur from the way we declared our hypothesis of test H_0 and H_1. We still have the right shape showing that both methods are increasing their probability of detection, but AMF appears here to be a more optimal method. We know from the lecture that this result is wrong, and that the Kelly method is the more optimal method.

Conclusion

This course objective was to introduce us the process of building a radar tracking system on the signal processing approach. We had to able to understand the different modelisation and assumption to be able to have a particular detector able to function on simplified hypothesis. We were then taught about two method of detection filter to mitigate the problems of unknown parameters, false alarm of the detectors. By implementing both method in matlab, we were able to learn the effect of each parameter involved in the detection method. As we did the comparison on the two methods, we acknowledge that the optimal method was the Kelly's method because the assumption made on this method which were closer to the real problem case. Instead of assuming to know the value of the disturbance covariance matrix like in the AMF method, we derive only a different detection based on the generalized likelihood ratio test approach. On our case, we work with smaller SNR making the Kelly method the better solution.