15/2/22

Problem 1

1) Noise samples are uncorrelated. It is convenient to apply an exponential weighting function following the signal shape. $SNR = \frac{V_P}{\sqrt{S_V*\frac{\pi}{2}f_{PA}}}\sqrt{\frac{e^2}{e^2-1}}$. In this scenario, $V_{P,MIN} = 39\mu V$.
2) With $T_{SAMPLE} = 10ns$ noise samples are correlated. It is convenient to give an exponential weight to the samples corresponding to 1 to the first sample and $e^{-\frac{T_S}{T_P}} = 0.9$ to the second sample. In this case, $N = \sqrt{S_V * \frac{\pi}{2}f_{PA}[(1+0.9^2)+2(0.9*0.9)]} = \sqrt{S_V * \frac{\pi}{2}f_{PA} * 3.43}$ while $S = V_P(1+0.9)$= $1.9V_P$. In this case, $V_{P,MIN} = 47.3\mu V$.
3) Optimum filter theory. $SNR_{OPT} = \frac{V_P}{\sqrt{S_V*\frac{1}{2}}}\sqrt{k_{bb}(0)} = V_P\sqrt{\frac{T_P}{S_V}} = 31.6\mu V$.

Problem 2

The load does not modify the shape of the signal, while its low pass filtering action on noise has a pole at 159MHz.

Overall electronics noise: $S_{E,TOT}$=4pA/$\sqrt{Hz}$.

PMT: dark current noise 0.0032fA/$\sqrt{Hz}$. SD=0.01A/W

PD: dark current noise 0.071fA/$\sqrt{Hz}$. SD=0.25A/W

1) T_{G1}=100ns

Case A) PMT

- Electronics noise is negligible with respect to dark current noise due to the PMT gain.
- If IB is much lower than $I_{S,MIN}$, then $I_{S,MIN}$=3.2pA. The hypothesis is verified.
- $P_{M,MIN}$=320pW.

Case B) PD

- Dark current noise is negligible with respect to electronics noise (no gain)
- If the electronics noise is dominant, then $I_{S,MIN}$=9nA. The hypothesis is verified.
- $P_{M,MIN}$=36nW.

Comment: PD has a better efficiency at the wavelength of interest, but the lack of gain makes the contribution of the electronics noise more important. In the end, PMT offers better sensitivity in this scenario.

2) Study of T_{Gm}= mT_{G1}

Case A) PMT

- We need to compare only signal and dark current noise (electronics noise is lower than dark current noise)
- The hypothesis of IB much lower than $I_{S,MIN}$ is valid for m<<1000.

- For m>>1000, $I_{S,MIN}$ is proportional to 1/m (dark current noise is dominant) while for m<<1000 , $I_{S,MIN}$ is proportional to 1/sqrt(m). (see theory for more details).

Case B) PD

- Already for m=1 electronics noise signal noise was negligible so even more for m>1. $I_{S,MIN}$ is always proportional to 1/sqrt(m). (see theory for more details).

3) Noise is white except for the integration due to the RC load. However, the time constant of the load is as short as 1ns so noise of multiple pulses is always uncorrelated. In this scenario, taking N samples is the same as having a gate as long as NT_{G1}.