Adaptive PSK Modulation Scheme in the Presence of Phase Noise

25-28 June, 2018
Kalamata, Greece

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Millimeter-Waves Systems and Phase Noise

Phase noise is one of the major impairments affecting severely performance of millimeter-waves (mmWaves) systems. This paper addresses the problem of link adaption for coherent and non-coherent phase modulated signals subject to phase noise. In contrast to usual link adaptation techniques, we propose a scheme exploiting an estimation of not only the Signal-to-Noise Ratio (SNR) but also of the phase noise variance, which is essential to achieve reliable communications.

System Model

Phase Noise

Oscillator phase noise may be described by the sum of two processes

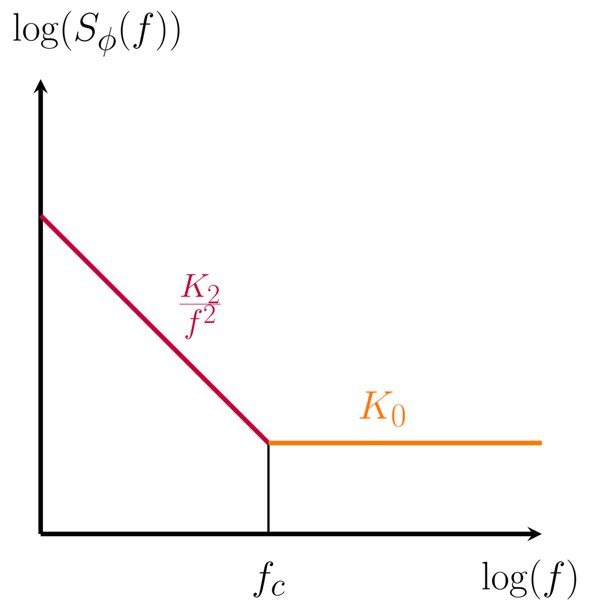
$$\phi_k = \phi_{g,k} + \phi_{w,k},$$

A white **Gaussian** phase noise

$$\phi_{g,k} \sim \mathcal{N}(0, \sigma_g^2), .$$

And a cumulative **Wiener** one

$$\phi_{w,k} = \phi_{w,k-1} + \delta\phi_{w,k},$$
$$\delta\phi_{w,k} \sim \mathcal{N}(0, \sigma_w^2).$$



mmWaves Channel

Expectations from theory that **the mmWaves channels are dominated by the line-of-sight component** have been confirmed by measurement campaigns. We consider a complex AWGN channel impacted by phase noise

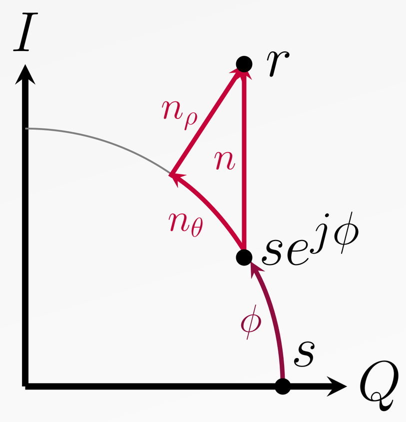
$$r_k = s_k \cdot e^{j\phi_k} + n_k.$$

Millimeter-waves communications demand a tremendous amount of power and so require high-efficiency and wide-bandwidth power amplifiers. Therefore, **(Differential) Phase Shift Keying is highly valuable** - with a constant envelope property it offers an efficient use of power amplifiers.

Phase Shift Keying over Gaussian Phase Noise

We exploit a **high SNR assumption** to derive the channel likelihood function [1] from the system model

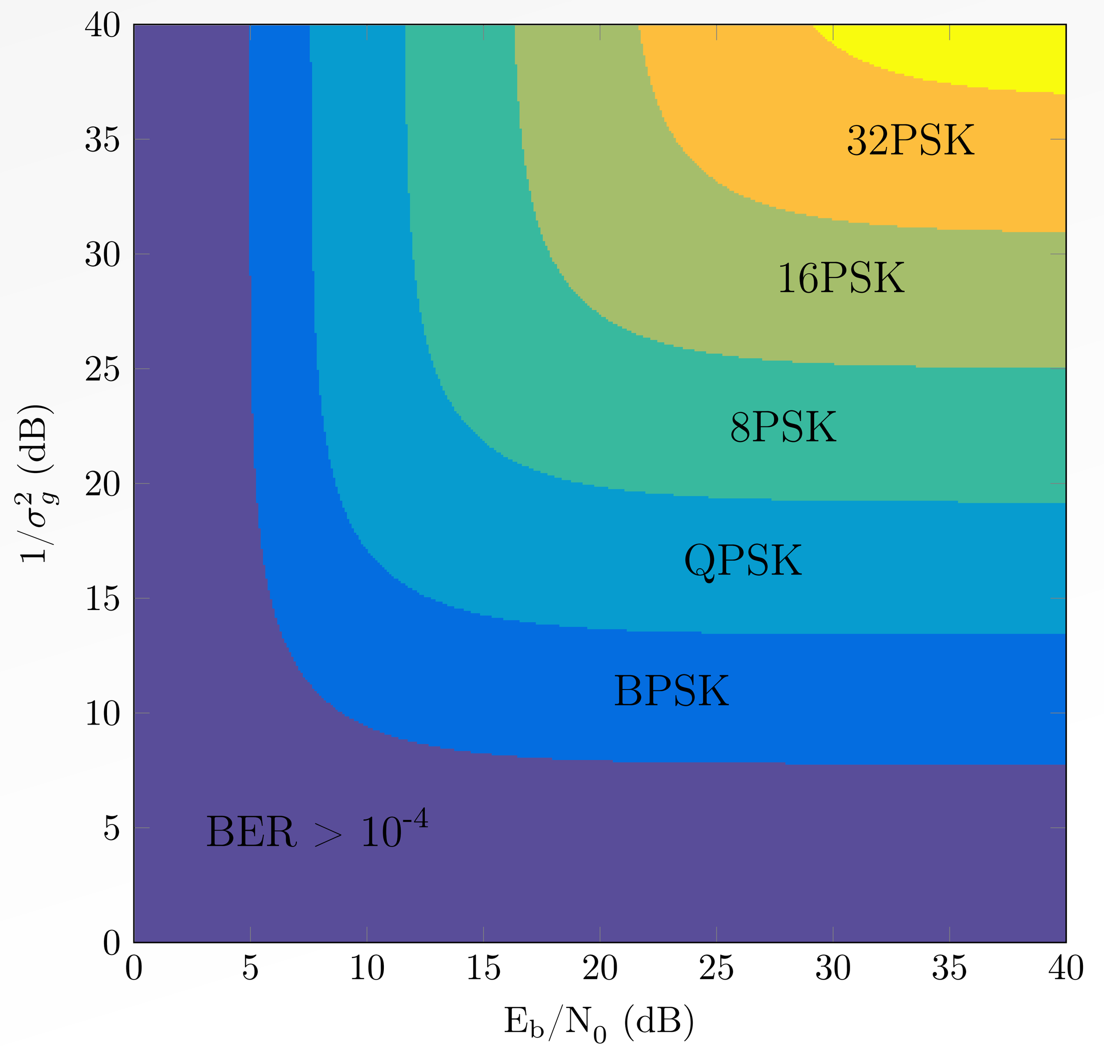
$$p(r_k|s_k) = \frac{\exp\left(-\frac{1}{2}\left(\frac{(|r_k| - |s_k|)^2}{\sigma_n^2} + \frac{(\angle r_k - \angle s_k)^2}{\sigma_g^2 + \sigma_n^2/E_s}\right)\right)}{2\pi\sqrt{\sigma_n^2(\sigma_g^2 + \sigma_n^2/E_s)}}.$$



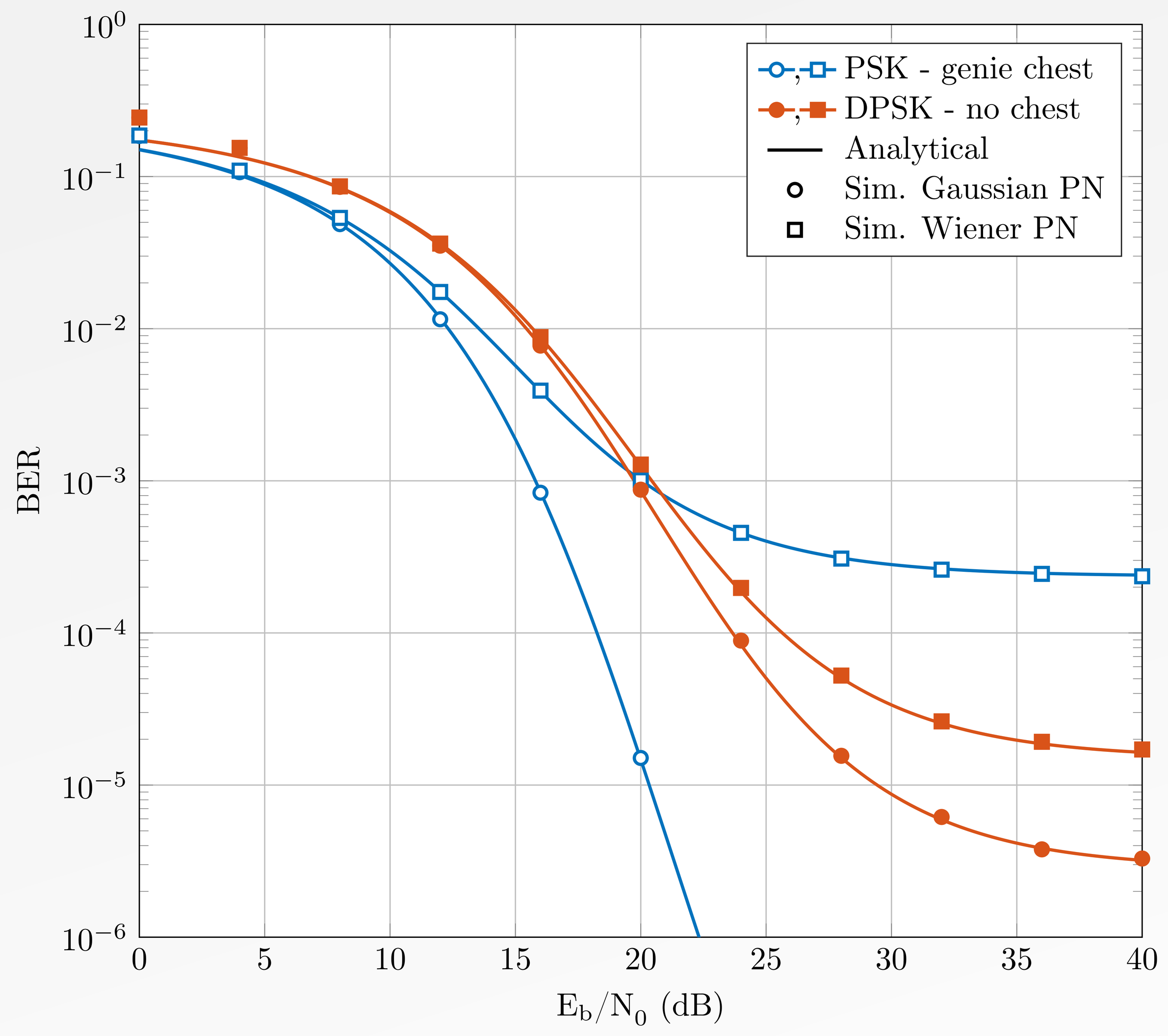
This leads to **closed-form expressions of bit error rate performance** and to the **optimum estimators of the thermal and phase noise variances**

$$\hat{\sigma}_n^2 = \frac{1}{N}\sum_{k=1}^{N}(|r_k| - |s_k|)^2, \qquad \hat{\sigma}_g^2 = \frac{1}{N}\sum_{k=1}^{N}(\angle r_k - \angle s_k)^2 - \frac{\hat{\sigma}_n^2}{E_s}.$$

The modulation order can be efficiently adapted to maintain the error rate below a fixed target.



Differential Modulation over Wiener Phase Noise



The DPSK is more robust than PSK only for strong cumulative PN ($\sigma_w^2/\sigma_g^2 > \lambda$).

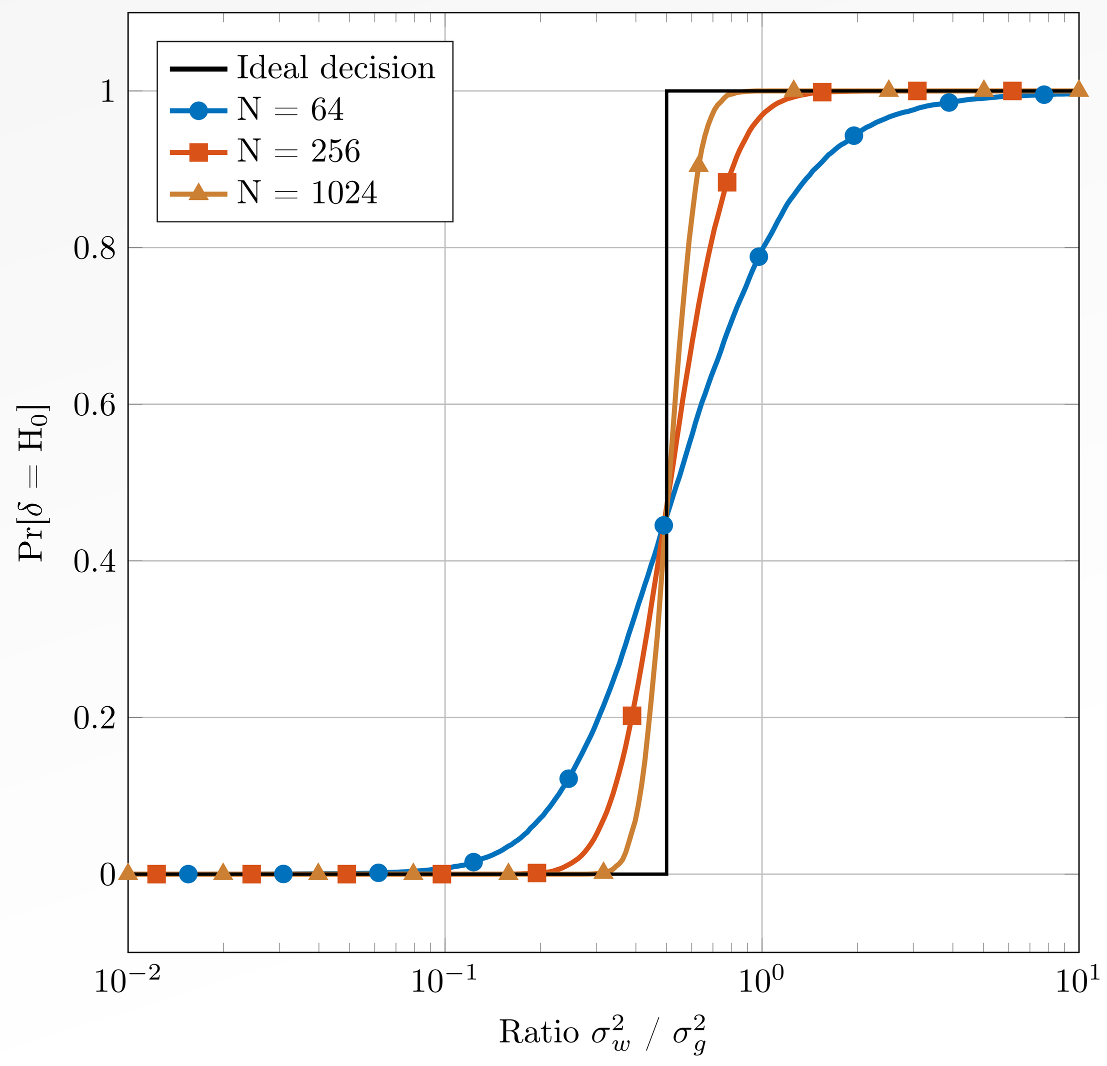
Is the cumulative phase noise strong enough to advantage a differential modulation?

$$H_0: \text{Wiener PN}, \quad \text{if } \sigma_w^2/\sigma_g^2 > \lambda \text{ fixed},$$
$$H_1: \text{Gaussian PN}, \quad \text{otherwise}.$$

Then the link adaptation decision δ is

$$\delta(\boldsymbol{r}) = \begin{cases} \text{DPSK}, & \text{if } S(\boldsymbol{r}) > \varphi(\lambda) \\ \text{PSK}, & \text{otherwise} \end{cases},$$

where S **is the proposed statistical test inherited from the financial field [2].**



Conclusion

- We adressed the problematic of **link adapation** for phase modulated signals.
- **Estimations of both SNR and phase noise variance** are essential to maintain robustness.
- We **proposed a detection test** to determine when the use of a differential modulation is beneficial.

References

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